AN EXPERIMENTAL ANALYSIS OF PERCEPTUAL DISCRIMINATION IN THE CAT: THE EFFECTIVE PROPERTIES OF OBJECTS AND THE DISCRIMINATORY BEHAVIOR OF THE ANIMAL

BY

WALTER FRANCIS DAVES

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by

Walter Francis Daves

Department of Psychology
Duke University

Date: 9-7-63

Approved:

Karl Zener

Karl E. Zener, Supervisor

Mercedes Gaffron

Norman Guttman

T. T. Diamond

Talmage Peele

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Psychology in the Graduate School of Arts and Sciences of Duke University

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ABSTRACT

(Psychology-Experimental)

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Two experiments were conducted to determine for the cat in an object-discrimination situation the effective properties of objects differing in multiple properties. The behavior of the animals was also observed in order to relate characteristics of discriminatory behavior to the effective object properties, and to allow the determination of properties of the retinal image of the objects when a discriminatory choice was manifested.

Experiment I. Two cats were trained to discriminate a vertically-moving smooth gray hemisphere (positive) from four horizontally-moving rough gray truncated pyramids (negative). For three additional cats the pyramid was positive and the hemispheres negative. Tests were run to determine which of the four properties--movement direction, texture, outline shape, and three-dimensional shape--alone or in combination, provided the basis for discrimination. Test objects, differing from the negative objects in one, two, or three of the four properties were presented along with the four unchanged negative training objects (negative-unchanged context). When thus tested, no cat chose the test object on the basis of movement direction alone. Each pyramid-positive cat would choose the test object on the basis of at least two of the three remaining single properties. One hemisphere cat chose only on the basis

of outline singly, and the other chose only on the basis of the texture-outline-three-dimensional shape combination. The position of choice was related to the effective property, in that texture choices were made near the objects, while outline and three-dimensional shape choices were made primarily at a distance.

Experiment II. Five hemisphere-positive and five pyramid-positive cats were trained on the problem above, but with all objects moving horizontally. They were tested both in the negative-unchanged context and in a context in which the positive training object was unchanged, and was presented with four identical negative objects differing from it in one or two of the three properties: texture, outline, and three-dimensional shape. A control situation was introduced in which the brightness relationship between positive and negative training and test objects was reversed.

As in Experiment I, the pyramid cats chose on the basis of all three properties tested singly in the negative-unchanged context and the hemisphere cats chose only on the basis of outline singly. Single properties were ineffective for the pyramid cats in the positive-unchanged context. Outline was effective for the hemisphere cats in both contexts. On the basis of this datum, the cats were assumed to have been reacting primarily to the properties of the positive object, not to those of the negative object.

By considering the effective object properties and the place at which choice on the basis of each was made, the characteristics of the retinal image of each training object at the time of choice were inferred. The analysis, after taking into account the brightness-control results, suggested that the border characteristics of the retinal image were effective for both hemisphere and pyramid cats, whereas the internal features of the image were effective only for the pyramid cats. These results were interpreted to indicate

the influence of tactual sensory consequences of perceptual behavior upon the effective properties of the image and of the object. Supporting data--both from observation of qualitative characteristics of discriminatory behavior in these experiments and from an independent experiment--were presented. The bearing of this interpretation upon the comparative study of visual perceptual processes and the visual function of thalamocortical sensory systems was considered.

Certain of the findings were discussed in terms of similar findings reported for the rat and the monkey by other investigators.

ACKNOWLEDGMENTS

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I should like to express my thanks to the supervisor of this dissertation, Dr. Karl E. Zener, for his many suggestions, constructive criticism, and personal support. Dr. Mercedes Gaffron's original and stimulating ideas provided much of the conceptual groundwork upon which these experiments were based. Because of the support of Dr. Irving T. Diamond, I was able to gain experience in the handling of cats in behavioral experiments, and some of the data discussed here were obtained while I was working in his laboratory. I should also like to thank Dr. Norman Guttman for a critical reading of the manuscript, and for the many helpful suggestions arising therefrom. The conscientiousness and skill of Mrs. Alfreda Kaplan, who typed the final copy of this dissertation, are much appreciated.

This work is dedicated to my wife, Susan, whose support and encouragement never failed to come through when they were needed.

W. F. D.

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INTRODUCTION

In the present experiments, the focus of interest is upon visual object discrimination in the cat. The primary question which these experiments are designed to answer is: When a cat learns to react differentially to objects which differ in a number of properties, which of these properties are effective in mediating the discrimination? An additional concern of these experiments is that of studying the discriminatory behavior of the animal, both in order to determine the role of discriminatory behavior as a factor related to the nature of the effective properties of objects, and as a device for determining the nature of the retinal image of the discriminanda at the time a discriminatory reaction is made.

In the following section the problems stated above will be discussed in relation to more general problems in the areas of the comparative psychology of visual perceptual processes and of the role of neural functioning in vision. Subsequently, a review of previous findings relevant to the present problems will be presented. Finally, some general considerations of method as related to the present problems will be discussed.

General Considerations Relevant to the Present Problem

One of the present emphases is upon determining the effective proper-

ties of objects, "objects" being one of several partially independent phases of the visual environment. (Other phases, the properties of which could be focused upon for study are the surround upon which objects are located, the energy source with which they are illuminated, and the energy reflected from object and surround in the direction of an eye of a perceiving organism.) This emphasis reflects a general concern for determining the biological role that visual perceptual processes play in a given animal's adaptation to its environment. The study of object-properties has a bearing upon this problem, in that the visually guided reactions of animals would appear to be primarily in relation to objects (such as food, prey, a member of the same species, etc.). In this regard it would be instructive to determine whether or not animals differing grossly in biologically-determined adaptive modes (e.g., type of food eaten, nocturnality vs. diurnality, etc.) tend to react to different properties of objects, and, if so, whether the nature of the different properties reacted to is related to such adaptational differences. Obviously, such a task could not be accomplished in a single, or even a few experiments. On the other hand, the problem would appear to warrant investigation. Consequently, the present experiments, which deal with the properties of objects reacted to by the cat, were conducted with the aim of facilitating the comparison of perceptual processes in cats with those in other animals, particularly mammals.

The study of effective properties of objects also has a bearing upon the problem of the nature and function of physiological mechanisms or processes that might be termed selective, modifying, or, in general, organizational. For example, the electrophysiological work of Lettvin, Maturana, Pitts, and McCulloch (e.g., 1961) indicates that the retina of the frog performs a rela-

tively complex analysis upon the information contained in the retinal image, abstracting, as it were, certain features of this information. The nature of certain classes of information abstracted turns out to be relatable to the natural behavior of the frog in relation to certain classes of stimulus objects. Thus, one class of neurons in the optic nerve of the frog seems to be especially responsive to the presentation of a small, fly-like spot, moving in relation to an articulated background. (Frogs naturally eat flies.) Another group of neurons is especially responsive to a large, dark contrast border moving across their receptive fields. (Frogs naturally run away from large, moving objects.) While such striking psychological-physiological correlations may not be immediately apparent in the case of, for example, the cat, it is suggested here that, at the psychological level, the investigation of selective mechanisms would require a determination of the effective properties of objects.

Obviously, a detailed understanding of the relationships between effective properties of objects and the operation of selective mechanisms as inferred from the results of electrophysiological experiments would, among other things, require one to determine the nature of the retinal image of objects reacted to. In this regard, the present emphasis upon effective object-properties may be considered, on the one hand, as a convenient starting place for a more detailed analysis of the selection of properties of the retinal image, the nature of which may be inferred from knowledge of the physical conditions (i.e., the location of the animal in relation to the objects reacted to) present at the time of reaction.

If, on the other hand, as is implied above, the nervous systems of animals are organized primarily to enable them to deal with objects, then the rationale for the emphasis upon object properties would appear to have a

stronger basis than mere convenience. The implication of the fact that most objects reacted to in biologically representative situations are three-dimensional is that certain "object-properties" or retinal image properties can be studied <u>only</u> with the use of three-dimensional objects. While the retinal image produced by an object may be duplicated, for a stationary animal and eye, by a photograph of the same object, it is safe to say that the animal and eye are rarely stationary. The consequence of this is that certain dynamic features of the retinal image (e.g., motion of different parts of the image of the object, both in relation to other parts of the object and to the surround) which are considered by Gibson (1958) to be adequate stimuli for a number of visually guided reactions in animals, can be studied only with the use of three-dimensional objects.

One aspect of the rationale behind the second major emphasis of the present study--that of determining the role of the discriminatory behavior of the animal in object-discrimination--is implied in the above discussion. Thus, a careful study of the discriminatory behavior of the animal may be expected to provide facts from which one can infer when and where the discriminatory reaction was initiated (i.e., the place, in relation to the object, at which it was "chosen"). Knowledge of the place at which choice is made would, in turn, enable one to infer the characteristics of the retinal image at the time of choice.

One kind of selective mechanism that, for quite understandable reasons of technical difficulty in experimentation, has been relatively neglected in physiological and psychological investigations is that related to the perceptual behavior of the animal. This topic is treated in a recent article by Zener and Gaffron (1962). These authors suggest that "perceptual behavior" is a very

important determinant of the nature of the perceptual processes involved in an organism's reaction to a given object or situation. (The term "perceptual behavior" includes all behavior that serves to modify the state, including the activation, of the receptor mosaic. Head and eye movements are obvious examples of perceptual behavior in vision.) Furthermore, they suggest that the neural states associated with the execution of perceptual behavior may have profound effects upon the transmission of sensory information at all levels of the system, and, consequently, upon the resulting perception. The role of motor processes in vision has also been recently stressed by Sperry and his co-workers (1955, 1960).

Considering these suggestions in the light of the present argument, the study of perceptual behavior would appear to be particularly relevant to the study of object properties. In the first place, the obvious fact should be pointed out that the characteristics of objects may be appreciated via other modality systems than the visual system, and, furthermore, that any interaction of animals with objects (e.g., prey) necessarily involves a number of modality systems. From this consideration the question arises as to the nature and visual perceptual effect of the interactions that must occur between, for example, vision, somesthesis, and the vestibular sense in the approach of an animal to an object, and in the consummation of the animal-object interaction, which might involve the animal's killing the (prey) object and eating it. More specifically, a problem of particular relevance to the study of object properties is that of the effect of multi-modal interaction with objects upon the effective <u>visual</u> properties of objects. That problems such as these are intimately related to the problem of the role of "perceptual behavior" in object-discrimination is seen in the fact that the execution of perceptual behavior must always have multi-modal sensory consequences. However,

<u>all</u> behavior having multi-modal sensory consequences is not necessarily perceptual behavior. It may be necessary, for example, to distinguish eye movements <u>qua</u> "exploratory," <u>qua</u> "reflex," and perhaps <u>qua</u> "orienting" behavior. The points to be made here are (1) that eye movements or movement of any other part of the body, <u>qua</u> "exploratory" behavior, may reasonably be classified as perceptual behavior; (2) that, regardless of the particular kind of behavior, a number of modality systems are involved; and (3) that the effect upon visual perception of such intermodal interaction is a question which has yet to be answered. Consequently, one of the more general purposes of the present experiments is to begin to determine the nature of such effects.

A Review of Previous Findings

<u>Preliminary distinctions</u>. In this section a number of experiments having a bearing upon the present problem will be discussed. Since one of the major orienting considerations underlying the present research is the comparison of species with regard to the effective properties of objects, the present discussion will include experiments relevant to the comparison of the cat with one other animal. The other animal chosen is the monkey, since a considerably larger number of object-discrimination experiments has been done using monkeys as subjects, than has been done using other animals, for example, the rat. Results of experiments using other animals as subjects will be discussed after presentation of the results of the present experiment.

Harlow has suggested that a distinction be made between stimulus-objects and stimulus-patterns.

> Discriminations which can be made on the basis of the external configuration of the objects <u>or</u> between some differentiating characteristic of the total surface (as color or brightness) are defined as stimulus-object

> discriminations. Pattern discriminations are here defined as discriminations in which the only differentiating characteristic upon which the choice can be made is the difference between figures painted or fastened on larger identical stimulus-objects. (1945a, p. 213)

This distinction is a useful one, from the point of view of discussing the kinds of discriminanda employed in experiments using the Wisconsin General Test Apparatus, and will be maintained here. However, as Harlow implies, "pattern" is also a property of the surface of the stimulus-object, and can be regarded in the same context as outline shape or color—i.e., all three are object-properties. The same point can be made in regard to patterns presented upon cards, which, in turn may be presented against doors which the animal is trained to open, although exactly what constitutes the "object" in such a case is less easy to determine.

Object-discrimination experiments. A large number of experiments has been performed in which animals were trained to discriminate three-dimensional objects. Only a few of them, however, have been concerned with determining the effective properties of objects, the large majority of them having been primarily concerned with the study of the acquisition of learning sets. Those experiments which have a bearing upon the present study fall into two categories: (1) Experiments in which the measure of effectiveness of a property is the ease with which a discrimination can be formed on the basis of that property, and (2) experiments in which objects differing in multiple properties are used, the measure of effectiveness being the scores obtained on "equivalence tests" (Kluver, 1933). In such tests new objects, similar to the original discriminanda in some respects but different in others, are presented to the animal. A property would be termed effective if new objects, differing only in that property, were reacted to in the appropriate way.

Two object-discrimination experiments falling into the first category

were performed by Harlow (1945a, 1945b). In the first experiment (1945a) he trained monkeys to discriminate a wide variety of stereometric and planometric objects, as well as patterns. The discriminanda differed in color, form, and size. The results obtained on the object-discrimination tasks indicate that "color differences, form differences, or combined color-form differences each offer adequate differentia for the formation of rapid discriminations. Areal differences . . . and shape differences are apparently less effective perceptual cues."* (1945a, p. 224)

In the second experiment (1945b) Harlow trained monkeys to discriminate stimulus-objects differing in color only, in form only, and in both color and form. He found that the discrimination was learned equally readily when the objects differed either in color alone or in color and form, and learning on these bases was easier than on the basis of form alone. The results of these two experiments suggest that, in the discrimination of objects, color is a dominant property for the monkey, although form is also effective.

Included in the second category of experiment is a study by Harlow and Poch (1945), part of which involved training monkeys to discriminate objects differing in color and form. The subjects were then tested by introducing objects in which color and form were varied in a number of ways. An interesting result is that, when the color of the positive and negative objects remained the same as in the training situation, with their forms reversed (i.e., positive color, negative form, vs. negative color, positive form) the performance of the animals tended toward chance. Thus, when the animals were presented with a conflict situation, neither color nor form tended to dominate. It may be sig-

*"Shape" differences involved, e.g., the differences between upright and inverted triangles, while "form" differences involved, e.g., the difference between a cross and a square.

nificant that these animals were trained to a criterion on each of the problems studied, whereas the animals in the experiments mentioned previously were trained only twenty-five trials on each problem. The results suggest that relative _ease_ of discrimination on the basis of a certain property does not necessarily imply the perceptual dominance of that property in a conflict situation. Furthermore, which property is dominant may be partly a function of the stage of training of the animal.

An experiment by Boyd and Warren (1957), while not primarily concerned with the present problem, none the less provides the only basis for comparing the cat and the monkey with regard to effective object properties.* These authors trained cats on the oddity problem. The discriminanda were objects differing in form, surface area, thickness, and brightness. In attempting to explain fluctuations in the animals' performance when tested for generalization of the oddity principle, they observed that the cats' performance was poorest when surface area and thickness of the objects were dissociated. Since during training, the thicker objects were also the larger in surface area, they reasoned that "area and thickness cues were associated during training, and dissociation prevented effective transfer, in spite of the presence of gross differences in contour and brightness." (1957, p. 259) The present writer interprets this to mean that volume may have been one of the more effective object properties in this situation. If such is the case, then this datum suggests a difference between cats and monkeys with regard to effective properties of objects.

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*Such a comparison, at least with regard to the color of objects, may not be very meaningful, since there is evidence (Meyer, Miles, and Ratoosh, 1954) that cats do not discriminate on the basis of wave length of light. However, there is no basis for knowing whether the monkeys mentioned above were discriminating on the basis of reflected wave length or brightness.

Pattern discrimination experiments. Experiments using pattern stimuli may also be classified according to whether the emphasis was upon ease of learning a discrimination on the basis of a certain property or upon the results of equivalence tests. Among the first class of experiments, those of Harlow (1945a, 1945b), mentioned above, also involved the study of pattern stimuli. In the first experiment (1945a) significant discrimination was obtained on the basis of both color and form, although color discriminations were easier if the colored patterns were large. There were no differences in ease of discrimination between large patterns on the basis of color and large or small patterns on the basis of form.

In the second study (1945b), pattern stimuli analogous to the stimulus objects already mentioned were employed. The results of training on the pattern discriminations were analogous to those obtained using objects, in that discrimination was superior on the basis of color, and the addition of form to color did not appreciably increase the ease of discrimination.

Essentially similar results were reported for the monkey by Warren (1953a), who used as a measure of effectiveness the percent correct on a number of ten-trial problems. Patterns differing in color, form, or size, alone and in the four possible combinations, were employed. Discrimination was again superior on the basis of color, and the addition of form or size differences to color did not appreciably increase the ease of discrimination.

While the available data suggest the dominance of color as a property of objects or of patterns for the monkey, other experiments suggest that the location of the differentiating color on the discriminanda is an important factor. Warren (1953c) reports data indicating that color differences were more readily discriminable when the color was at the border of the stimulus cards, suggesting that "the monkey responds more strongly to the borders than

to the centers of cards." (p. 235) These results were confirmed by Riopelle, Wunderlich, and Francisco (1958), who used concentric-ring patterns, with the location of the differentiating color varying from center to periphery of the patterns.

There is also an indication that, when form is the only differentiating feature of patterns, ease of discrimination depends upon the specific characteristics of the forms. Thus Warren (1953b) reports that pattern discriminations are easier for monkeys if a geometrically regular pattern is to be discriminated from a geometrically irregular pattern, than if two regular, or two irregular patterns are to be discriminated.

With regard to the ease of discrimination on the basis of various properties of patterns by cats, Smith (1951) has compiled data indicating that brightness discriminations are more easily learned than form discriminations.

Within the second category of experiments dealing with effective properties of pattern stimuli--those in which equivalence tests are run following training on patterns differing in multiple properties--the writer is aware of only one experiment relevant to the present problem. Mars and Warren (1961) trained dark-adapted cats in a two-choice discrimination box to discriminate luminous patterns differing in brightness, area, and "form" (ratio of horizontal to vertical dimensions of rectangles). The authors had previously established psychophysical functions for discrimination on the basis of each of the properties separately, and the patterns used in the combined-property training situation differed an equal number of j.n.d.'s in each of the three dimensions. After learning the problem the animals were tested in a conflict situation in which one positive property (e.g., brightness) was opposed to another positive property (e.g., area). The results "revealed that normal cats tended to respond to brightness more often than to size or form." (p. 90)

If any summary statement can be made on the basis of the literature reviewed here, it is that there is little evidence which would enable one to compare the cat and the monkey with regard to the effective properties of objects or patterns. However, certain tentative statements may be made: While color is certainly a dominant feature of objects or patterns for the monkey, form and size are also effective, and the location of the differentiating color on the object or pattern is critical. Furthermore, differences between forms are more effective if one of the forms is geometrically regular and the other one irregular. For the cat, on the other hand, the situation with regard to effective properties of objects is not very well known, although there is a suggestion that volume is a critical factor. For patterns, on the other hand, all available data indicate that brightness is a dominant feature. However, the situations in which pattern vision has been studied in the cat are not directly comparable to those employed with the monkey, since the patterns used have frequently been luminous, and the animals partly dark-adapted.

The relative lack of knowledge about effective properties of objects for animals is still reflected in a statement by Harlow: "Although our knowledge of the exact role of the perceptual variables influencing learning in chimpanzees and monkeys is incomplete, it is almost profound in comparison with our scanty knowledge of the perceptual characteristics of subprimate animals." (1951, pp. 215-216) This lack would not appear to be due only to the limited number of studies that have been done in this area, but also to the limited number of properties of objects that have been studied.

The role of perceptual behavior in discrimination. While many authors have reported the occurrence of perceptual behavior, such as head and eye movements, or "comparison reactions" in animal subjects in discrimination experi-

ments, there have been few systematic attempts to deal with the role of motor processes in perceptually guided behavior. Riesen and Aarons (1959), in studying the effects of visual deprivation on movement discrimination in kittens, found that exposure to patterned light was not sufficient to enable the animals to develop perceptually. Only those animals that were allowed to behave actively in relation to the visual environment were able to perform normally. Elsewhere Riesen (1958, 1961) has described in some detail the abnormalities in eye movements occurring in the chimpanzee and monkey after visual deprivation. It may be significant in this regard that he and Aarons (1959) do not report marked eye-movement defects, such as persistent nystagmus, in the kittens subjected to patterned light deprivation. The role of motor processes in visual discrimination obviously requires further study.

A General Consideration of Method

The scope and aims of the present experiments are considerably less broad than is implied in the preceding sections. These experiments constitute an attempt to determine for the cat in <u>one</u> object-discrimination situation the effectiveness of only a <u>few</u> properties of objects (four in Experiment I and three of the same four in Experiment II). An additional concern is the role of the animal's perceptual behavior in discrimination, particularly as a factor related to the selection of effective object properties.

If the results of such experiments are to be applicable to the interpretation of behavior in biologically representative situations, it would be desirable for the properties studied to be representative of properties of objects that the cat would be expected to encounter in its interaction with the environment. Furthermore, the objects used as discriminanda should differ in

enough properties to allow selective processes a chance to operate.

An additional requirement is that the experimental situation allow for the possibility of various kinds of discriminatory behavior to be manifest, since the likelihood of determining any relationship between effective object-properties and perceptual behavior would require that the cat not be forced by the situation into any one pattern of behavior.

EXPERIMENT I

This experiment was conducted in order to obtain preliminary data on the effectiveness for the cat of several stimulus object properties, acting separately and in combination. Direction of movement, texture, and shape were chosen for study, with shape being broken down into projected outline shape and three-dimensional shape.

Direction of movement was chosen because of casual observations, with which most people would agree, that cats appear to be interested in moving objects. While movement discrimination in the cat has received some attention in the literature (Kennedy and Smith, 1935; Kennedy, 1939; Riesen and Aarons, 1959), these studies employed rotating crosses as stimuli to be discriminated from stationary crosses. In the present study direction of movement (i.e., horizontal vs. vertical) was employed, since direction would appear to be a more natural characteristic of movement for the cat. The choice of direction of movement was also influenced by a recent study by Hubel and Wiesel (1962), who report cells in the cat's visual cortex to be selectively sensitive to contrast borders moving in a particular direction in their receptive fields.

Texture was chosen since it is undoubtedly a prominent feature of many objects that the cat might react to, although it is a property which, to the writer's knowledge, has not been studied in the cat as a visual object property to be discriminated.

Shape was chosen since it also is a prominent feature of objects to which the cat might react. The further breakdown of shape into outline shape and three-dimensional shape is perhaps somewhat artificial. However, the breakdown was made, primarily in order to distinguish between properties, such as outline, which may be considered as conceptually analogous to one property of two-dimensional stimuli--simple geometrical pattern--that has been studied a great deal in cats and other animals, and shape properties other than outline, which have received little or no attention in the literature.

The method of test. The method employed in the present study for determining the effectiveness of the qualities above is a modification of the "method of equivalent and non-equivalent stimuli" (Kluver, 1933). The first step was to train animals to discriminate stimulus objects differing in all four of the properties above. When a perfect, or near-perfect, level of performance was achieved, a series of "critical trials" was introduced, in which the positive object was changed so as to differ from the identical negative objects (four negative objects were employed in the present experiment) in one, two, or three of the four properties: movement, texture, outline, and three-dimensional shape. The rationale for determining effective properties is as follows: A property is considered to be effective if the animal consistently chooses a test object differing from the negative objects only in that property. The failure of the animal to do this leads to the conclusion that that property is ineffective. In the present experiments a property was considered to be effective if it elicited differential (correct) choice behavior three or more times out of a total possible of five ($p = .059$) or six or more times out of a total possible of ten ($p = .006$).

Observation of discriminatory behavior. A second major emphasis in this experiment is upon the observation of the discriminatory behavior of the

cat, in order to attempt to relate characteristics of discriminatory behavior to the results obtained on the critical trials. Since there is no _a priori_ reason to exclude any form of discriminatory behavior as potentially relevant, an attempt was made to record as accurately and as completely as possible all aspects of the cats' behavior. Such observation later proved to be humanly impossible for one experimenter, and, consequently, particular emphasis was placed upon the approach of the animal to the discriminands.

The development of a suitable training and testing method. A third (and logically prior) aspect of the present experiment involved the necessity for developing a workable training and testing procedure. Certain of the desiderata related to method have already been mentioned--i.e., having objects differing in enough representative properties to allow selective processes a chance to operate, and employing an experimental situation in which the cat is relatively free to behave naturally. An additional desirable feature of the experimental situation involves the rapid achievement by the cat of a high level of discrimination performance on the basic discrimination, relatively uncomplicated by such maladaptive (from the experimenter's point of view) forms of behavior as the position habit. Furthermore, the situation should be such that statistically reliable information as to the effectiveness of the properties tested can be obtained in a minimum number of trials, since the study of the animal over a long time span would possibly complicate the findings. Since the means whereby these desirable features of the experimental situation and the training procedure could be achieved were relatively unknown at the initiation of the experiment, each cat in this experiment was treated slightly differently from the others.

Subjects

Subjects were five house cats--four females and one male. They were selected from a pool of cats maintained by Duke University. Selection was made on the basis of disposition and apparent health. They were housed in galvanized cages in a colony room, cleaned daily, and fed a standard commercial cat food except when they were being run in the experiment. They appeared to be in excellent health throughout the experiment. Three of the cats, P4, H7, and P12, were experimentally naive. Cats H3 and P8 had been run briefly in a visual discrimination experiment in a two-choice discrimination box, in which the task was a discrimination between horizontal and vertical stripes. P8 had been rejected from this experiment because of a persistent position habit. H3 and H7 were trained to choose the smooth hemisphere, and P4, P8, and P12 were trained to choose the rough pyramid. ("H" and "P" in front of the identification numbers refer to hemisphere and pyramid, respectively.)

The Experimental Situation

Apparatus. The essential features of the apparatus* used are: (1) a platform to accommodate the cat's home cage, which was used as the starting box; (2) a detention box, separating the starting box from (3) a trapezoidal choice box; (4) a panel containing five doors in a row, which led to (5) five goal boxes. An outline drawing of the apparatus is presented in Figure 1. The inside of the apparatus was painted flat black. Stimulus objects were attached to 3/16 inch aluminum rods, which, in turn, were attached to one of two bars

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*This apparatus was constructed by Messrs. James Dyer and William Ward. It was developed as a part of a minor experiment in perceptual discrimination in the cat conducted under the direction of Dr. Karl Zener.

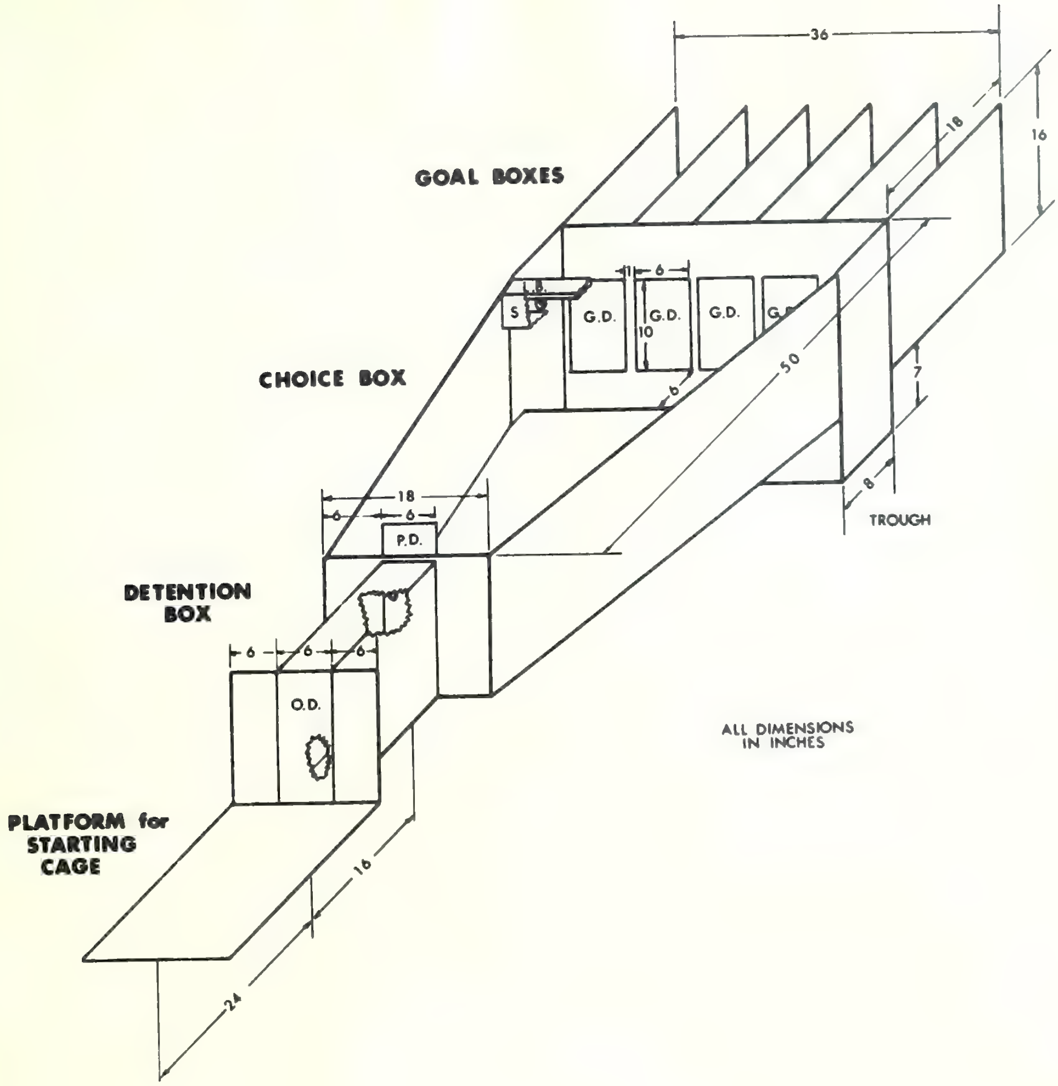


Figure 1. Diagram of Apparatus Used in Experiments I and II.

Legend: O.D. = opaque door; P.D. = plexiglass door; L.B. = light bar, containing five seven-watt bulbs; S = shield and reflector for light bar; G.D. = door to goal box (five in all); trough contains shade and (Experiment II only) five seven-watt bulbs.

spanning the choice box approximately one inch in front of the doors. The location of these bars relative to the rest of the apparatus is indicated in Figure 2. One of the bars moved horizontally, the other moved vertically. Each bar was driven by a continuously-variable speed motor. The amplitude of the approximately sinusoidal movement was 1-7/8 inches. The duration of the cycle of movement was approximately three seconds. A forty-watt incandescent bulb in a gooseneck lamp was placed above and in front of the home cage-starting box. The detention box was illuminated by a seven-watt bulb, and the stimulus objects by a row of five seven-watt bulbs situated above and approximately eight inches in front of the row of doors. The light from these bulbs was diffused through a ground plexiglass panel. The choice box was covered on the top by a gray plastic window screen. A trough, eight inches wide and seven inches deep separated the floor of the choice box from the panel of goal box doors. A plank two inches wide covered the trough on the side of the choice box, thus extending the floor of the choice box two inches in the direction of the doors. Within the trough was a black window shade, which could be raised by the experimenter, in order to prevent the cat from correcting an incorrect choice.

This apparatus appears to meet certain of the requirements mentioned above, in that (1) the choice box is sufficiently large to allow the cat to behave in a relatively natural manner; (2) a number of properties of three-dimensional objects can be studied, including object movement; (3) the discriminatory behavior of the cat can be readily observed; (4) the probability of a correct choice by chance is 0.2, compared with 0.5 in the standard two-choice box. This means that the chance probability of occurrence of three or more correct choices in a row is .008, and that of three or more correct out of five trials is .059. Thus, reliable performance can be demonstrated in a rela-

Figure 2. Photograph of Bars Used to Move Objects in Experiments I and II

Upper bar moves horizontally, lower bar moves vertically. Stimulus objects attached to 3/16 inch diameter aluminum rods, which, in turn, are attached to 5/16 inch diameter vertical rods indicated in the photograph. Each bar contains 5 vertical rods. Rods attached to vertically moving bar not visible in photograph.

tively few trials. Moreover, Fields (1935, 1953) suggests that the efficiency of learning of visual discriminations by rats is much greater in a five-choice, as contrasted with a two-choice, apparatus.

The stimulus objects. The objects used in training and testing are indicated in Table 1; photographs of similar objects appear in Figure 3. Training objects consisted of four smooth hemispheres (A) and four rough truncated pyramids (B). The hemispheres, three inches in diameter, were made from balsa wood, sealed with a wood filler, and sanded smooth. The pyramids were fashioned from an expanded polystyrene insulating material (Armalite, by Armstrong). After the pyramids were cut from the raw material, they were lightly sprayed with Krylon clear plastic spray, which partially dissolved the surface, thereby producing a reasonably hard, rough surface. (The maximum indentation of texture units was approximately 1/8 inch; minimum indentation was approximately 1/32 inch; average was approximately 1/16 inch.) Both sets of objects, as well as all test objects, were painted with a medium gray tempera. All objects were painted at the same time, and with paint from the same jar. They received several coats at first, and were repainted periodically.

Test objects for use on the critical tests were made from balsa or styrofoam, as indicated above, depending upon the requirements for texture. These objects were designed so as to differ from the negative training objects in one or two of the three object properties texture, outline, and three-dimensional shape. They included: a smooth pyramid (C) of approximately the same dimensions as the rough ones; a rough hemisphere (D); one smooth (E) and one rough (F) "pyramid," each with a circular base; one smooth (G) and one rough (H) "hemisphere," each with a square base. Manipulation of the direction of movement of the objects was affected by attaching the appropriate

Table 1

Description of Objects Used in Experiment I[a]

Object	Description
A	Smooth hemisphere. Diameter = 3 in.
B	Rough truncated pyramid. Base = 2-1/4 in. square; height = 2 in.; front surface parallel to base = 7/8 in. square.
C	Smooth pyramid, same dimensions as Object B.
D	Rough hemisphere, same dimensions as Object A.
E	Smooth pyramid, with 2-5/8 in. diameter circular base. Height = 2 in.; front surface parallel to base = 7/8 in. square.
F	Rough pyramid, otherwise same as Object E.
G	Smooth hemisphere, with 2-1/8 in. square base. Height = 1-5/8 in.; original hemisphere, from which square base was cut, was 3-1/4 in. diameter.
H	Rough hemisphere with square base. Same dimensions as Object G.

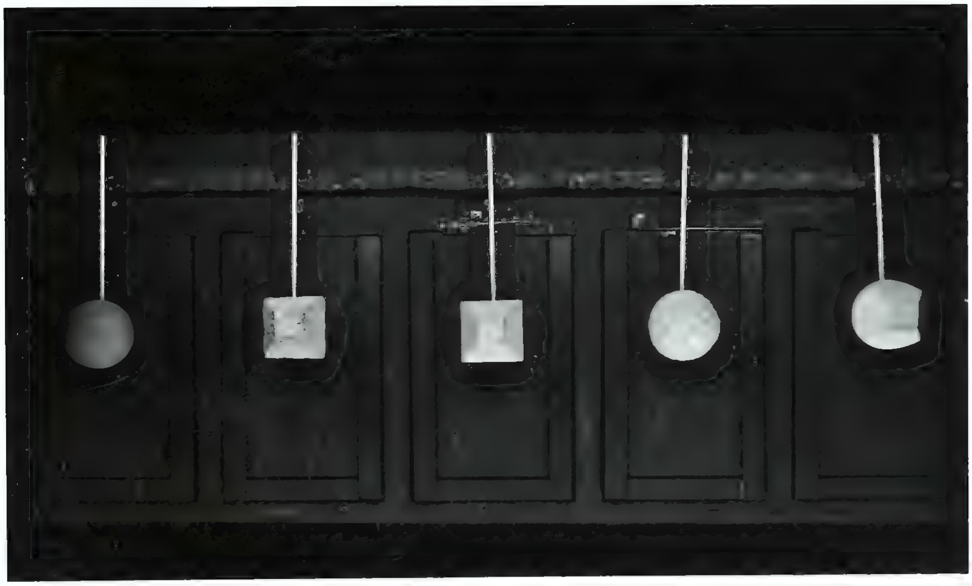
a. See also Figure 3, p. 27.

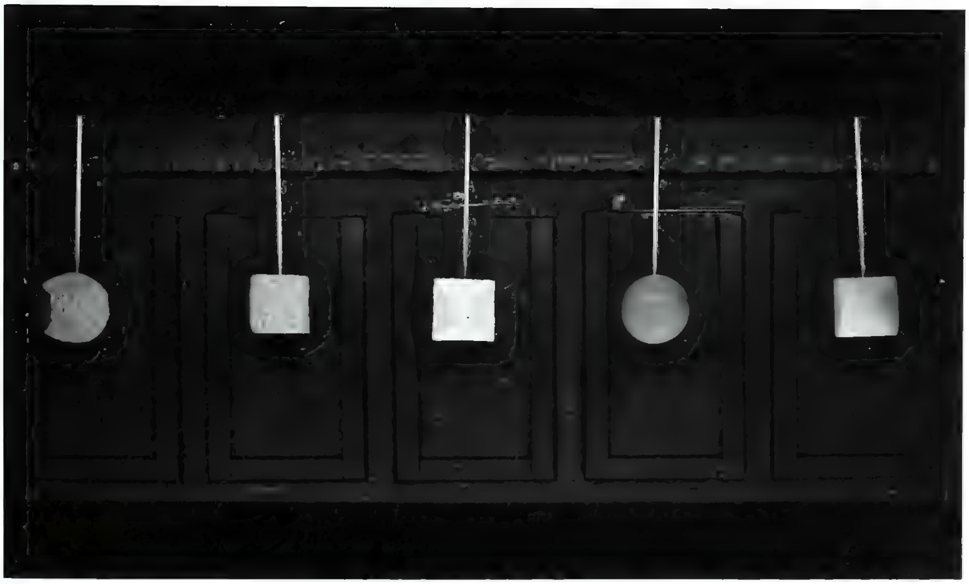
Figure 3. Photograph of Objects Similar to Those Used in Experiment I.

The objects depicted are the ones used in Experiment II, but, except for projected outline size, do not differ appreciably from those used in Experiment I.

Upper figure: Objects (left to right) A, B, C, D, and E. Object A appears darker in photograph than was actually the case. Object E turned slightly outward to indicate three-dimensional shape.

Lower figure: Objects (left to right) F, H, J, I, and G. Object F turned slightly outward, and appears darker than was actually the case. Objects J and I presented in center position to indicate brightness differences. Objects J and I were used only in Experiment II, in the brightness-control tests. (See text, p. 51)





training or test object to the appropriate rod. Thus, during training the hemispheres were attached to the vertically moving rod, and the pyramids were attached to the horizontally moving rod. During testing, if movement was to be one of the properties tested, the appropriate test object was attached to the rod moving in the direction opposite to that of the negative objects. If movement was not one of the properties to be tested, the test object was attached to the same rod as the negative objects. In either case, the negative objects always moved in the direction in which they moved during training.

The question of relative sizes of the objects was very difficult to deal with, particularly since they are relatively complex in shape. It is impossible, considering the present state of knowledge, to specify the physical dimensions related to "size" for the cat. Thus, there is no indication as to how surface area, thickness, projected area, and volume should be differentially weighted in specifying the phenomenal size of the objects for the cat. Consequently, what was done was to attempt approximately to equate the objects for phenomenal size for two human observers ([illegible] and [illegible]). After a first approximation, "that hemisphere" was "made a little larger," or "a small amount removed from that pyramid." The inadequacies of this method are apparent. However, it was determined at the time to be the most reasonable way to handle the problem of size, in lieu of an extensive study of stimulus variables influencing visual size discrimination in the cat.

Training procedure. At the beginning of each session the cat's home cage, with the cat in it, was taken from the colony room and placed on the platform of the apparatus, and the cage door opened. On each trial the following procedure was followed: The motors driving the horizontally and vertically moving rods were turned on, and the light above the animal's cage turned off. The door to the detention box was dropped, releasing the animal

from its cage. Three to five seconds after the animal entered the detention box the door to the choice box was raised, thus allowing the animal to enter the choice box and make a choice. A correct choice, however it was defined (see below), resulted in the cat's obtaining a morsel of ground horse meat (1/40 of the daily ration). Incorrect choices were treated differently, depending upon the stage of development of the method and the stage of training of the cat. In all cases in which the cat was to be kept from making further choices, however, the shade in the trough was raised to separate the cat from the stimulus objects, and the cat removed from the choice box.

One training session usually consisted of twenty trials, and one or two sessions were run per day. When two sessions were run in a day, they were spaced at no less than eight-hour intervals. The criterion for cessation of training and initiation of testing was approximately 90 percent correct for two or more sessions, although this varied somewhat from cat to cat.

The cats' feeding schedule was arranged so that they could obtain their complete ration of horse meat in the training or testing situation. Thus, each cat's daily ration was divided into forty small pieces of meat, which it could obtain in the forty trials usually run per day. If the cat failed to obtain part of its ration during a session, it was fed the remainder soon after termination of the session. On days in which only one session was run, the cats were fed the amount they would have received during the omitted session, at approximately the time the session would have been run.

In the early stages of training of cats #4 and #7, an attempt was made to train the animals to open the door behind the correct object. This method proved unsuccessful, in that reliable discrimination performance was never achieved. They appeared to focus their attention upon the doors, paying

little attention to the objects. A retraining period, in which they were allowed to enter the goal box only after contacting the object chosen, seemed to remedy the situation. Cats F3, F8, and F12 were trained to contact the correct object from the beginning.

The general training regimen involved a series of preliminary trials in which the positive stimulus-object was presented alone, and the cat trained to respond to it (i.e., either open the door behind it, or contact it, depending upon the stage of development of the method). The position of the correct object was varied unsystematically from trial to trial, in this phase and in all later phases of training. When the cat learned to do this, the four negative objects were introduced, and discrimination training begun. The shade was used to prevent the cat from making further choices on a given trial, although the exact circumstances dictating its use varied from cat to cat. All cats except F12 were allowed, on a given trial, to continue to make incorrect attempts (i.e., to contact negative objects or to attempt to open negative doors) as long as they appeared to the experimenter to be "object-oriented." Recourse to the shade was made when a cat appeared to be responding mechanically to every object it encountered, or when it showed signs of developing a position habit. For F12, ten "free" trials on the discrimination problem were allowed, in which the shade was not used. After that, the shade was pulled up on any trial in which two incorrect choices were made.

Whenever the discrimination behavior showed signs of breaking down, a few (as few as one) trials in which the positive object was presented alone, were run. A "breakdown" was variously defined, but usually involved two consecutive trials in which the shade had to be pulled.

<u>Test procedure</u>. The test phase was begun after the establishment of approximately 90 percent correct performance for two sessions on the dis-

crimination problem. Four or five test trials were run per session, each test trial following three or four training trials. In a test trial one of the test objects (Objects C-H; Table 1, p. 25, and Figure 3, p. 27) was substituted for the positive stimulus object, thus reducing differences between positive and negative objects to zero with respect to one, two, or three of the four properties present on the training trials. In Table 2 are indicated the objects used and the direction in which they moved for each test condition for both hemisphere-positive and pyramid-positive cats. The meaning of the term "property tested" is that the test object differed from the negative training objects, which were always present during test trials, only in the property or properties indicated in the left-hand column of Table 2.

For all cats except F12 the order of testing was as follows:

1. Ten trials on each of the test objects that differed from the negative object in only one property. Each object was presented on each door twice.

2. Five to ten trials per test object in which each of the properties tested in (1) above that failed to elicit five or more choice reactions ($p = .032$) were combined in groups of two. For example, if movement and texture differences both failed to elicit five or more correct choices when tested singly, they were combined in the second series of tests.

3. Five trials, in which all previously negative properties were combined by threes. For example, if movement, texture, and outline all failed to elicit five or more correct choices, either singly or in the three possible combinations by twos, these properties were combined in a single test object.

F12 was tested differently, in that she received five trials each, in random order, on all possible tests included in (1) and (2) above. In other

Table 2

Test Objects Used and Their Direction of Movement for Each Test Condition for Each Training Group in Experiment I

Property Tested[a]	Hemisphere Sets			Pyramid Sets		
	Single Object	vs.	Four Objects	Single Object	vs.	Four Objects
M	B_v[b]	vs.	B_h	A_h	vs.	A_v
T	C_h	vs.	B_h	D_v	vs.	A_v
O	F_h	vs.	B_h	[illegible]	vs.	A_v
3-D	H_h	vs.	B_h	E_v	vs.	A_v
MT	C_v	vs.	B_h	D_h	vs.	A_v
MO	F_v	vs.	B_h	G_h	vs.	A_v
M3-D	H_v	vs.	B_h	D_h	vs.	A_v
TO	E_h	vs.	B_h	H_v	vs.	A_v
T3-D	G_h	vs.	B_h	F_v	vs.	A_v
O3-D	D_h	vs.	B_h	C_v	vs.	A_v
MTO	E_v	vs.	B_h	E_h	vs.	A_v
MT3-D	G_v	vs.	B_h	F_h	vs.	A_v
MO3-D	D_v	vs.	B_h	C_h	vs.	A_v
TO3-D	[illegible]	vs.	B_h	B_v	vs.	A_v

a. Abbreviations in Property Tested column: M = movement; T = texture; O = outline; 3-D = three-dimensional shape; MT = movement plus texture, etc.

b. The capital letters "A" through "H" refer to the objects described in Table 1. The subscripts "v" and "h" refer, respectively, to vertical and horizontal movement.

words, combinations by twos were tested regardless of the effectiveness of the member properties when tested singly. Testing of [illegible] was discontinued after Phase 1, since it became increasingly difficult to get her to run.

On the test trials the animal was allowed to enter the goal box behind whatever object it chose (i.e., contacted) on that trial. On the interspersed training trials, however, it was rewarded only when it chose the correct object on the first attempt. Errors on these trials were treated just as they were during training--i.e., the shade was used.

Behavioral data. On each training and each test trial the approach and choice behavior of the animal was observed and recorded. Standard data sheets were used, which provided, for each trial, a place to make a line drawing indicating the cat's path to the goal. Behavior directed to any objects, such as looking, pawing, or nosing, was recorded. Any other items of possible interest, such as exploration of the choice box, playfulness, distraction by anything other than the objects, were noted.

Approaches were scored as correct or incorrect, according to whether the cat first approached a positive or a negative object. (On the test trials, the test object was considered to be the "positive" object). A choice was defined as contacting the object, either with paw, nose, or vibrissae. Choices were scored as correct or incorrect according to whether the cat first contacted a positive or a negative object. In cases in which the cat contacted an object, and then moved on to another object, the object first contacted was considered to be its choice on that trial, although it was admitted to the goal box behind the last object chosen. Such trials were not very frequent. Some cats came to prefer to stand in front of the objects rather than contact them. Whenever this occurred, they were required to wait for one or two seconds before the experimenter would open the door.

After the completion of Experiment II, the individual protocols of Experiment I were re-scored, and the choices categorized as to whether they were manifest at a distance from the object panel or in its vicinity. The criteria for scoring were as follows:

1. Choice made at a distance (F).

   a. Direct pathway from detention box to object chosen.

   b. Smooth, curved pathway from detention box to object chosen; point at which direction of movement changes must be clearly behind a line 18 inches from the goal box doors.

   In either (a) or (b) above, the cat may look at only the object chosen and the object(s) immediately adjacent to the object chosen, and then only once at each object. The object in front of which the cat stops must in all cases be the object eventually chosen (contacted).

2. Choice made at an intermediate distance (I).

   a. Broken pathway to goal. Animal stops in one or more places before approaching an object. The point at which it stops must be behind the 18 inch line.

   b. Smooth pathway from detention box to goal, in which the cat is observed to survey the objects while moving towards them. (I.e., cat makes head movements back and forth while moving.)

   In either case, the cat's behavior, once it crosses the 18 inch line, must conform to that specified above for a score of F.

3. Choice made near the objects (N).

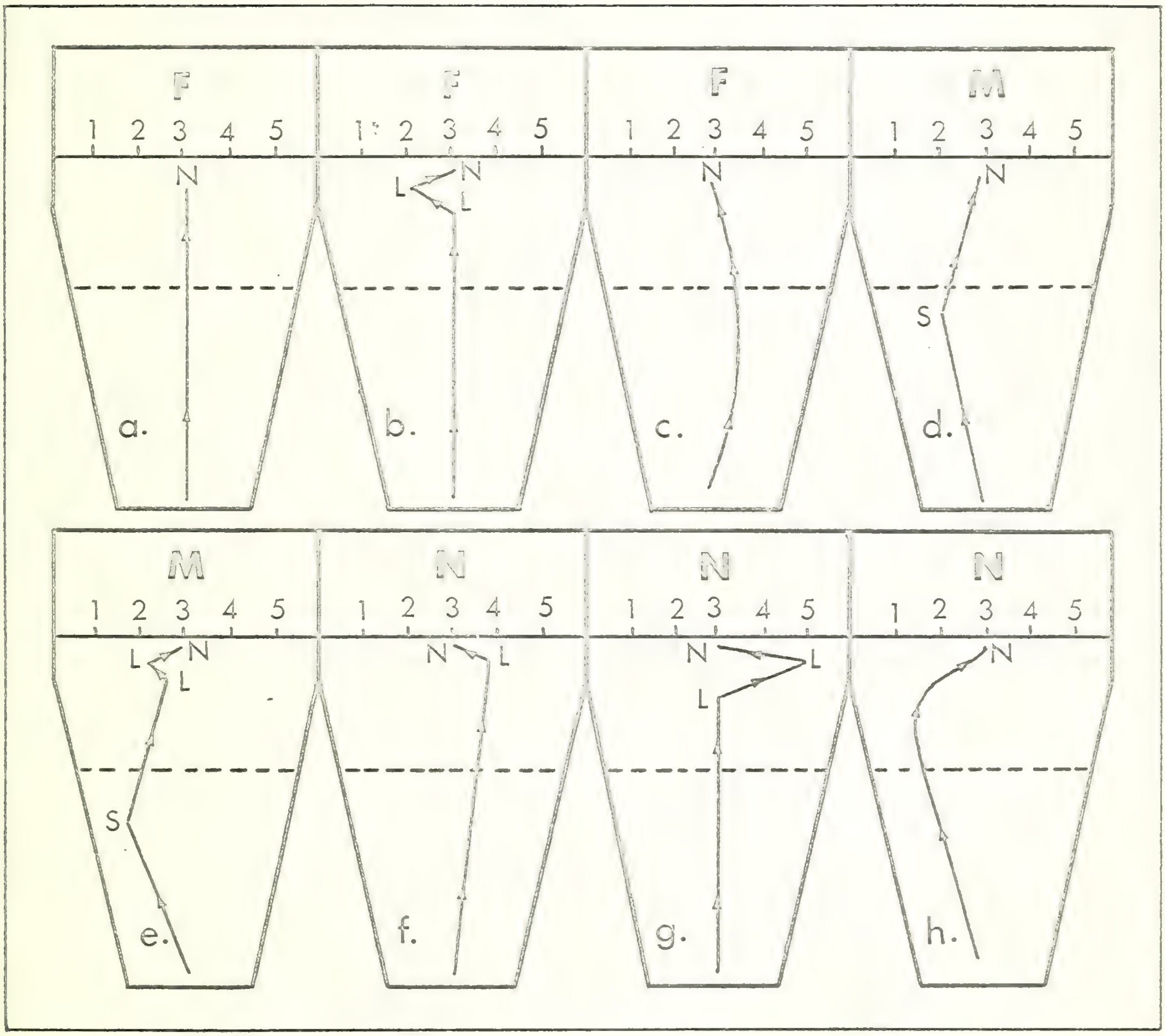
   Included in this category is any behavior involving a choice that does not conform to that specified for a score of F or I. Thus, the cat may approach one object, subsequently choosing another, or it may approach the object eventually chosen, but, before choosing it, look at one or more objects not adjacent to the object chosen, or it may look at adjacent objects more than once each. Choices are also scored N when a smooth, curved pathway is made, the turning point of which occurs beyond the 18 inch line.

Some examples of choices scored F, I, and N are provided in Figure 4.

Figure 4. Diagrams illustrating scoring system used in Experiments I and II. Each box (a - h) is scale drawing of floor plan of choice box. Dashed lines indicate position of line 18 inches in front of goal box doors. Numbers in upper part of boxes indicate positions of objects.

Animal's path of approach to objects indicated by arrows. Behavior in relation to objects indicated where it occurred. Abbreviations: S = animal moves head back and forth (surveys objects); L = animal stops in front of object (looks at it); C = animal contacts object (with nose, paw, or vibrissae).

Scores are indicated in bold face above numbers. Each example is for choice of object in Position 3. Boxes a, b, c: choices scored 3; boxes d, e: choices scored 2; boxes f, g, h: choices scored 1. (See text for elaboration of scoring criteria.)


F
1 2 3 4 5
N
a.
F
1 2 3 4 5
L N
L
b.
F
1 2 3 4 5
N
c.
M
1 2 3 4 5
N
S
d.
M
1 2 3 4 5
L N
L
S
e.
N
1 2 3 4 5
N L
f.
N
1 2 3 4 5
N L
L
g.
N
1 2 3 4 5
N
h.

Results

Original training. Since the animals were treated differently during training, such measures as number of trials to criterion would not be very meaningful. However, such measures are, perhaps, grossly indicative of the usefulness of the various methods used. F4, one of the cats originally trained to open the door behind the positive object, failed to achieve a high and stable level of performance after 290 trials, approximately 135 of which were on the discrimination problem. The remainder of the trials were run with the positive stimulus alone. Following this phase, 25 trials were run in which it was retrained to contact the positive object alone. After 52 more trials on the discrimination problem, F4 was performing well enough to begin testing. M7, whose initial training was similar to that of F4, was run for 190 trials, only 28 of which were on the discrimination problem. The rest were on the positive object alone problem. Performance appeared to be deteriorating somewhat, even on the single object problem. It was retrained to contact the single object for 32 trials, and, after 62 additional trials, its performance was sufficiently high to begin testing. H3 and F8 were trained to contact the object from the beginning. H3 reached criterion after 134 trials, 69 of which were on the discrimination problem. F8 achieved criterion after 121 trials, 75 of which were on the discrimination problem.

All of the above animals received two or three days' prior adaptation to the apparatus. They were fed in it, and allowed to explore it. On the other hand, F12 began training on the first day it was introduced to the apparatus. This cat reached criterion in 120 trials, 95 of which were on the discrimination problem.

It is interesting that the cats trained to contact the object from the

beginning learned quite rapidly to go to the positive object when it was presented alone. In no cat were more than 12 trials required. On the other hand, the cats originally trained to open the doors learned quite rapidly to approach a door that was opened approximately fifteen degrees inward (i.e., with the food not visible). They performed less well when the door was completely closed, however, and showed more breakdowns in performance, even on the problems in which the single object was presented alone. It would appear that the behavior of the animal immediately preceding reinforcement should, if a high level of performance is to be achieved rapidly, be directed toward whatever the experimenter would _like_ the discriminanda to be.

Training trials run on test days. The choice (contact) performance of all cats except P8 was maintained at a high level of accuracy on the training trials run on the test days. With the one exception, choice performance was frequently 100 percent correct, and never below 90 percent correct. The performance of P8 was more variable, ranging from 67 to 100 percent correct, with a mean level of 86 percent correct. The percentage of correct approaches was generally lower than the percentage of correct choices, and there were more individual differences in approach behavior. The average percentages ranged from 55 percent for P6, to 95 percent for P4 and H7. H3 and P12 both approached the correct object 85 percent of the time.

Test trials: general. The results of the test trials are presented in Tables 3 and 4. In Table 3 are indicated, for each property tested for each cat, (1) the number of times that it directly approached the test object, regardless of whether it chose (contacted) that object (A+), and (2) the total number of correct choices, regardless of mode of approach (C+). For the approach and choice scores the asterisk indicates that that many correct approaches

Table 3

Number of Trials (T), Number of Correct Approaches (A+), and Number of Correct Choices (C+) of the Test Object for Each Cat for Each Property or Property-Combination Tested in Experiment I

Property Tested[a]	Cat Number														
	F3			F7			F4			F6			P12		
	T	A+	C+	T	A+	C+	T	A+	C+	T	A+	C+	T	A+	C+
M	10	2	2	10	4	3	10	2	2	10	1	4	5	2	2
T	10	4	4	10	2	3	10	4	2	10	4	8*	5	3*	5*
O	10	6*	6*	10	4	3	10	6*	6*	10	2	4	5	4*	3*
3-D	10	5	1	10	3	3	10	8*	8*	10	4	9*	5	5*	5*
MT	5	2	2	5	1	1	5	4*	4*				5	3*	5*
MO	5	3*	0	5	1	1	5	4*	4*				5	4*	3*
M3-D	5	4*	1	5	1	2							5	5*	5*
TO	5	4*	0	7	2	1	5	5*	5*				5	4*	5*
T3-D	5	4*	1	5	1	1							5	4*	5*
O3-D	5	4*	2	10	7*	1							5	5*	4*
MTO	5	4*	1	5	1	1									
MT3-D	5	5*	3*	5	0	0									
MO3-D	5	5*	1	5	1	0									
TO3-D	5	5*	5*	5	4*	4*									

a. The abbreviations in the Property Tested column are the same as those used in Table 2, p. 32.

*Number of approaches or choices reaches or exceeds criterion (see text).

or choices could occur by chance a maximum of approximately six times in one hundred.

On the basis of the data presented in Table 3, it can be seen that, taking either approach or choice scores as indices of differential behavior in relation to the test object, four out of the five cats would react to a test object when it differed from the negative objects in only one property. All five cats would react differentially toward the test object when it differed from the negative objects in two properties. The results obtained on the individual property and property-combination tests are indicated below.

Movement. Inspection of Table 3 reveals that, regardless of the index of effectiveness (i.e., approach or choice), movement differences alone were ineffective. Thus, no animal approached or chose the test object more often than would be expected by chance when it differed from the negative objects only in movement. Moreover, except in two cases (the movement-texture combination for F4 and the movement-texture-three-dimensional shape combination for M3), movement differences did not "help" the effectiveness of other single or combined properties.

Outline. Outline differences were effective alone for three of the five cats (M3, F4, and F12). It may be significant that two of these cats (F4 and F12) were trained to choose the pyramid, and only one (M3) to choose the hemisphere.

Three-dimensional shape. Three-dimensional shape differences were effective for three cats (F4, F8, and F12). It is striking that all three of these cats were trained to choose the pyramid, and that three-dimensional shape was effective for neither of the two hemisphere-trained cats.

Texture. Texture differences alone were effective for only two of the cats (F8 and F12). Again there is a suggestion of a difference between hemi-

sphere and pyramid cats, in that these two cats were both trained to choose the pyramid, and neither of the hemisphere cats would choose on the basis of texture alone.

Property-combinations. The effectiveness of property-combinations was studied in only four of the animals. In only three of these is the comparison of results of combined-properties tests with those of single-property tests meaningful, since the performance of F12 on the single-property tests was, except for the movement tests, at a relatively high level. For the three remaining cats, some degree of increased effectiveness in the combined-properties tests is seen. For H7, only the original positive training object was chosen more often than would be expected by chance, although this cat would approach the test object differing from the negative objects in only outline and three-dimensional shape (the two in combination). For H3, outline alone was effective, although among the combined-properties tests only the movement-texture-three-dimensional shape combination, and the texture-outline-three-dimensional shape combination would elicit a significant number of correct choices. On the other hand, this cat would approach the test object on the basis of any property-combination except the movement-texture combination. For P4, the movement-texture combination would elicit both approaches and choices, although neither of these properties was effective when tested singly.

The failure of cat H3 to choose the test object on the basis of certain combinations involving outline, although outline was effective singly, may be due to the fact that the tests for outline were conducted earlier than the combined-properties tests. Thus, the diminution of effectiveness of outline may reflect a process of differentiation, whereby the animal becomes more particular with regard to what constitutes an object to be reacted to positively.

Individual differences within groups. Within the two training groups, there are individual differences as to the effectiveness of the various properties and property-combinations. The essential differences between the two hemisphere cats (H3 and H7) have already been mentioned in the immediately preceding section. Within the group of cats trained to choose the pyramid, it can be seen that, for P12, all of the single properties except movement were effective, both for approach and for choice. For P8, no property was effective for approach, although texture and three-dimensional shape were effective for choice. (Approach scores would not appear to be very meaningful for this cat, since on the training trials this cat's approach scores were generally low.) For P4, outline and three-dimensional shape were effective, for both approach and choice.

While there is little basis in the data recorded in the present experiment for explaining the individual differences observed, it would appear that further study of this matter would be desirable. It is conceivable that a more careful observation of the discriminatory behavior of the animals would reveal some relationship between individual differences in effective properties and the animals' dominant mode of behaving in the situation.

The point at which choice is manifest. In Table 4 are presented the percent correct choices scored F or W (indicated in the table as F'), and the percent scored W. Only those properties which elicited a greater than chance number of correct choices are indicated (i.e., only those properties identified by asterisks in the choice (C+) column of Table 3, p. 39, are included). The percents are in reference to the total possible number of correct choices that could possibly have been made.*

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*For the F+W category, the total possible correct is the number of trials

Table 4

Number of Trials (T), and Percent of Total Possible Trials in Which Correct Choice Was Made at a Distance (F') and Near (N) the Objects, for Each Cat for Each Property Tested that Was Effective for Choice in Experiment I (See Text)

Property Tested[a]	Cat Number														
	M3			M7			F4			F8			F12		
	T	F'[b]	N	T	F'	N	T	F'	N	T	F'	N	T	F'	N
M															
T										10	30	63	5	60	100
O	10	40	33				10	50	17				5	60	00
3-D							10	80	00	10	40	83	5	100	00
MT							5	80	00				5	60	100
MO							5	80	00				5	40	33
M3-D													5	60	100
TO							5	100	00				5	80	100
T3-D													5	80	100
O3-D													5	80	00
MTO															
MT3-D	5	60	00												
MO3-D															
TO3-D	5	100	00	5	80	00									

a. The abbreviations in the Property Tested column are the same as those used in Table 2, p. 32.

b. The formulae for computing F' and N are: $F' = \frac{C_F - C_N}{T} \times 100$; $N = \frac{C_N}{T - C_F}$

where C_F = number correct scored F; C_N = number correct scored N; [illegible] = number correct scored [illegible]; T = number of trials run. See text for explanation.

It can be seen that, only in the case of texture was a greater percentage of choices made in the near, as contrasted with the far, situation. In all other cases except one, the correct far choices exceeded the correct near choices by at least thirty percentage points. Even in the exception (M3: outline singly) there was a greater percentage of correct choices made at a distance, although the difference was not as great as in the other cases.

Discussion

Discussion of results. There are several potentially important features of the data presented above. One unexpected finding was that movement was ineffective. This finding would appear to be quite important, since it implies that only certain kinds of movement are effective. The movement used in the present study was quite steady, and relatively slow, and both positive and negative objects were moving. It may very well be that only a relatively jerky, rapid movement would interest the cat in a situation such as the present one.*

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run. For the N category the total possible is the number of trials run minus the number of correct trials scored F or M. The rationale for this computation is as follows: According to the criteria for scoring F, M, or N, a correct choice scored F or M could not possibly have been scored N as well. An incorrect choice scored F or M, however, could have been corrected before the object incorrectly "chosen" was contacted. In such a case the choice would have been correct and scored N. Consequently, the number correct scored F or M should not enter into the picture when the correct choices scored N are considered, whereas the number incorrect scored F should be considered.

*Cat F4, after the termination of this experiment, was studied further by Drs. K. Zener, M. Gaffron, and Mr. Hugh Mills. An attempt was made to train this cat to discriminate identical objects that differed only in direction of movement. Although the method of approximation was used, in which the differences in speed of movement were quite gross at first, and gradually reduced, the discrimination was achieved only after a relatively long and arduous training period. This datum tends to confirm the present findings with regard to the ineffectiveness of the kind of movement employed here.

Of major interest is the suggestion that the properties of the objects that become effective are some function of the nature of the positive and/or negative objects. In this regard, one possible factor related to the differences between hemisphere and pyramid cats (i.e., the effectiveness of texture and three-dimensional shape for pyramid, but not for hemisphere cats) is the fact that the test trials were conducted in a context in which the negative training objects were unchanged, and all test objects (i.e., all "correct" objects) had negative, as well as positive features. Exactly how this might affect the results is a matter for speculation, but it would appear that the use of an additional test situation--for example, one in which the odd and correct "test objects" are actually the (unchanged) positive training object, and the four "negative" objects have some positive and some negative properties, would be desirable.

Another feature of the data that warrants further investigation is that correct choices of the test object, when texture was its only distinguishing property, were made predominantly near to the objects, whereas correct choices made on the basis of outline and three-dimensional shape were made predominantly at a distance. While this datum may simply be a reflection upon the acuity of the animals, it may also reflect a relationship between the nature of the effective stimulus and perceptual behavior, either as a function of the individual cat or of the nature of the training situation (i.e., which object is positive). Thus, the fact that two of the pyramid cats (for whom texture was effective) may have been able to inhibit choice of the incorrect object approached, and then choose the rough object, may have a bearing upon the kind of discriminatory behavior learned in the training situation.

Discussion of method. Although the method proved, in general, to be successful, a number of technical and procedural shortcomings became apparent during the course of the experiment. In the first place, illumination of the

objects was only from above. This had the effect of producing a very dark, inverted "V"-shaped shadow on the underside of the pyramids, which possibly confounded three-dimensional shape and outline, at least at a distance. It was also noticed that, although the objects were painted with the same paint, there were slight differences in brightness between the hemisphere and the pyramid, due to texture differences and differences in disposition in space of the surfaces of the two objects in relation to the source of illumination. Although overall brightness also varied with the position of the objects in the stimulus array (objects at the sides of the apparatus were less brightly illuminated than objects in the center) and the cats were responding reliably on the training trials regardless of the position of the correct object, it was deemed advisable to correct this situation. Another problem was that, although the objects were equated for phenomenal size for two human observers, the effectiveness of outline at a distance could have been due to the difference in projected surface area of the objects. Consequently, in order to be relatively certain about at least <u>one</u> quality--outline, it appeared desirable to equate the objects for projected surface area.

A problem appears to have arisen in the running of combined-properties test trials <u>after</u> the single property tests. If the cats tend to become more particular with regard to the objects chosen, comparison of single-property tests and combined-properties tests would only be meaningful if the tests were unsystematically distributed in time. The change in testing procedure in the case of P12 reflects this concern.

With regard to the matter of training the animals in the original problem, the procedure used for P12 appears to be the best. It would appear reasonable that, during any process of adaptation to the training apparatus,

the cat might learn things about the situation that would interfere with the learning of the problem. Ideally the cat should learn as quickly as possible the fact that, in order to get food, a relatively specific thing has to be done--i.e., contact an object. Adaptation, in which the cat is fed without working, would appear to be an interfering feature here.

In regard to the choice response to be required of the animal, the results of the present study indicate that contacting the object itself is the best response to use in that cats trained to make this response from the beginning achieved a high level of performance more rapidly than cats first trained to open the door behind the correct object.

EXPERIMENT II

In Experiment I, a method was adapted for training cats to make object discriminations, and for testing them to determine the properties of the objects that were effective in mediating the discrimination. The results of this experiment indicated that the apparent effectiveness of the properties of the objects differed from cat to cat and seemed to depend upon which object was positive. It was suggested that these apparent differences may have been due to the fact that the test trials were run in a context in which the negative training objects were unchanged, the positive test object having both positive and negative properties. It was also suggested that the place at which the discrimination was made was related to differences in effectiveness of certain properties. Experiment II was conducted in order to check these findings, and to explore further the relationships among effective properties, the positive training object, and the place at which choice was made.

The object-properties studied in this experiment are texture, outline, and three-dimensional shape, alone and in combination. Direction of movement was eliminated from this experiment because it was not effective for any of the cats in Experiment I, whereas each of the other three properties was effective for at least some of the cats. However, in order to change the situation as little as possible, all objects were presented moving horizontally.

In the execution of this experiment, a more nearly standard training procedure was employed, and certain new technical and procedural features were incorporated into the apparatus and experimental design. These changes will be discussed in the appropriate sections below.

Subjects

Subjects were ten experimentally naive young adult house cats. There were two males and eight females. They were selected and maintained in the same way as the subjects in Experiment I. All subjects appeared to remain in good health throughout the experiment. The cats were randomly divided into two groups, each composed of four females and one male. One group, consisting of cats F19, F30, F33, F35, and F37, were trained to choose the rough pyramid, and the other group, consisting of cats M14, F31, F32, F34, and M36, were trained to choose the smooth hemisphere.

The Experimental Situation

Apparatus. The apparatus was basically the same as that used for Experiment I, except that a row of five seven-watt incandescent bulbs was placed in the trough in the lower corner in front of the objects. The light from these bulbs was diffused through a piece of sanded plexiglass. This addition rendered the top and the bottom of the front surfaces of the objects approximately equal in illumination.

Stimulus objects. The stimulus objects used in the experiment are indicated in Table 5 and Figure 3 (p. 27). Just as in Experiment I, they were constructed from balsa wood or styrofoam and painted with a medium gray tempera

Table 5

Description of Training and Test Objects Used in Experiment II[a]

Object	Paint	Description
A	1 Bl / 4 W[b]	Smooth hemispheroid. Base = 2-1/2 in. diameter; height = 1-3/8 in.
B	"	Rough truncated pyramid. Base = 2-1/8 in. square; height = 2 in.; front surface parallel to base = 7/8 in. square; indentation of texture varied from approximately 1/32 in. to 1/8 in., with an average of approximately 1/16 in.
C	"	Smooth pyramid, same dimensions as Object B.
D	"	Rough hemisphere, same dimensions as Object A; texture same as in Object B.
E	"	Smooth pyramid, with 2-1/2 in. diameter circular base. Height = 2-1/8 in.; front surface parallel to base = 7/8 in. square; circle was cut from pyramid with 2-5/8 in. square base.
F	"	Rough pyramid. Texture identical to that of Object B; other dimensions are those of Object E.
G	"	Smooth hemisphere with 2-1/8 in. square base. Height = 1-1/2 in.; original hemisphere, from which square was cut, was 3 in. diameter.
H	"	Rough hemisphere with 2-1/8 in. square base. Texture same as in Object G.
I	1 Bl / 2 W	Except for paint, identical to Object A.
J	1 Bl / 10 W	Except for paint, identical to Object B.

a. See also Figure 3, p. 27.

b. 1 Bl / 4 W means that one part black tempera paint was mixed with four parts white tempera paint.

(one part black to four parts white). In order to equate the objects for projected outline size and, at the same time, keep them reasonably equivalent in three-dimensional size, it was necessary to forego using perfect hemispheres. The "hemispheres" were, then, actually hemispheroids, although the term "hemisphere" will be retained here. Four additional smooth hemispheres (I) and four additional rough pyramids (J) were constructed for use in tests run in order to control for brightness differences between the objects. (See testing procedure below.) The new hemispheres were painted so that they would be noticeably darker than the darkest of the "brightness-normal" objects (one part black to two parts white), and the new pyramids were painted noticeably lighter than the lightest of the brightness-normal objects (one part black to ten parts white). All objects were attached to the horizontally-moving rod during both training and testing. The amplitude of movement was 1-7/8 inches, and the duration of the cycle was three seconds.

Training procedure. The training procedure used in this experiment was more nearly standard for all subjects than in Experiment I, and was chosen with the aim of producing reliable discrimination performance as rapidly as possible. The procedure chosen was essentially that used with cat P12 in Experiment I. The first phase of training was begun without any prior adaptation to the apparatus. In this phase the cat was presented with the positive object alone, the position of the object varying unsystematically from trial to trial. If, in the process of exploring the box, it happened to contact the object, the door behind the object was opened and the cat induced to enter the goal box and eat the morsel of horse meat, which served as the incentive. If the cat showed no interest in the object, the door behind the object was "wiggled" in an attempt (usually successful) to get the cat's attention. It was usually, however, not admitted to the goal box until it con-

tacted the object. In no case was it allowed to push the door open. This phase of training was continued until the cat approached and contacted the object, without previously contacting any door or showing any signs of disturbance, on three successive trials. The number of trials and days required for mastery of this phase of the problem varied from 8 (day 1) to 29 (day 4), with a median value of 21 trials (2 days), and seemed to depend primarily upon the timidity of the individual cat. More timid cats required a longer time.

The next phase of training consisted of ten consecutive trials in which the positive object was presented in each of the positions twice, along with the four negative objects. The cat was allowed to contact any and all objects, but was rewarded only when it contacted the positive object.

In the third phase of training, the one positive and four negative objects were presented as in the previous phase, with the position of the positive object varying unsystematically. The cat, however, was allowed only two attempts (contact-choices) on a given trial. The second incorrect attempt on a trial was punished by the pulling up of the shade between the cat and the objects, to prevent further choices on that trial. On such occasions the cat was removed from the choice box and returned to the starting box. Whenever it proved necessary to use the shade on two consecutive trials, the next trial was run with only the positive training object present. Such trials were continued until the cat approached and contacted the object immediately on one trial. On the next trial the four negative objects were reintroduced and the cat again allowed only two attempts to find the positive object. This procedure was repeated until the cat was correct on the first attempt on fourteen out of the last fifteen trials of a thirty-trial session. Once this criterion was achieved, the cat was overtrained for three days (ninety trials). During overtraining only one attempt per trial was allowed. The

shade was used after an incorrect attempt, and the cat returned to the starting box.

Only one session per day was run. While most of the cats could not be induced to run thirty trials per day during the early stages of training (i.e., the first day or two), as many trials as possible were run up to a maximum of thirty. Thereafter, thirty trials per day were run. A correct choice was always rewarded with a morsel of ground horse meat, which constituted approximately 1/30 of the cat's daily ration. Thus, it would obtain its entire ration during a day's session. If it failed to obtain the entire ration, it was fed the remainder shortly after the end of the session.

Testing procedure. Three major changes were made in the test procedure. In the first place, a new series of test trials was added, in which the positive training object was unchanged, serving as the odd and correct object on training trials. This object was presented along with four identical, but changed "negative" objects, which were changed so as to have certain positive as well as certain negative properties. This situation will be termed the "positive-unchanged" context. It is to be contrasted with the only situation used in Experiment I, in which the negative training objects were unchanged on the test trials, and were presented with an odd and correct object that had both negative and positive features. This latter condition will be called the "negative-unchanged" context. (Figure 5, p. 66, provides illustrations representing the test situation for each training group, property, and context.)

The second change in method of testing involved the testing of both single and combined properties over the same period of time. This was done in order to minimize any effects of differentiation, which, although manifest in only one cat in the previous experiment, is a factor which could interfere with

interpretation of results.

The third major change involved the introduction of a series of trials in which the brightness relationships between hemisphere and pyramid (or the test objects derived from them) were reversed. This was done in an attempt to rule out any contaminating effects due to the intrinsic differences in brightness between hemisphere and pyramid.

The specific procedures followed during testing are as follows: After completion of overtraining, the test phase was initiated. During this phase thirty-two trials were run per day. In every test day each of the twelve property-test conditions indicated in Table 6 was met once. The order of presentation of the test conditions was unsystematically varied from day to day. The manner in which the test trials were interspersed in the training trials was varied somewhat for F14, M19, F30, M31, M32, and F33, although no more than two consecutive test trials were ever run. For M34, F35, M36, and F37, the order was invariably as follows: Five consecutive training trials were followed by six test trials, each of which was separated from the other by one training trial, for a total of eleven trials. This sixteen-trial series was then repeated, yielding a total of thirty-two trials. The position at which a given test object was presented varied from day to day, although in the long run each object was presented an equal number of times at each point.

Test trials were run for a total of fifteen days. On the first five of these test days the training and test objects were "normal" with respect to their brightness relationship (i.e., all objects were painted with the same paint). These tests will be referred to as the "brightness-normal" tests. On the last ten days of testing, five "brightness-normal" days of tests were run, plus five days on which the brightness relationships between the positive and

Table 6

Test Objects Used for Each Test Condition for Hemisphere-positive and Pyramid-positive Cats in Experiment II

		Brightness-normal Condition		Brightness-reversed Condition	
Positive Object	Property Tested[a]	Positive-unchanged Context	Negative-unchanged Context	Positive-unchanged Context	Negative-unchanged Context
Smooth hemi-sphere	T	A vs. D[b]	C vs. B	I vs. D	C vs. J
	O	A vs. G	F vs. B	I vs. G	F vs. J
	3-D	A vs. E	H vs. B	I vs. E	H vs. J
	TO	A vs. H	E vs. B	I vs. H	E vs. J
	T3-D	A vs. F	G vs. B	I vs. F	G vs. J
	O3-D	A vs. C	D vs. B	I vs. C	D vs. J
Rough pyra-mid	T	B vs. C	D vs. A	J vs. C	D vs. I
	O	B vs. F	G vs. A	J vs. F	G vs. I
	3-D	B vs. H	E vs. A	J vs. H	E vs. I
	TO	B vs. E	H vs. A	J vs. E	H vs. I
	T3-D	B vs. G	F vs. A	J vs. G	F vs. I
	O3-D	B vs. D	C vs. A	J vs. D	C vs. I

a. The abbreviations used in this column are identified in Table 2, p. 32.

b. For each entry, the first letter refers to the object listed in Table 5 that is odd and "correct" in that test condition. The second letter refers to the object listed in Table 5, of which there are four in that test condition. Thus, "A vs. D" means that one smooth hemisphere (A) was presented with four rough pyramids (D).

negative objects were reversed (i.e., the darker hemispheres or the brighter pyramids were substituted for the normal ones). On any "brightness-reversed" day, all trials--including the interspersed training trials--were run with the brightness relationship reversed. The order of occurrence of brightness-normal and brightness-reversed test days varied from cat to cat, but no more than two consecutive brightness-reversed days were run for any cat. The exact order for each cat is indicated in Appendix A, in which the asterisks in the C+ columns indicate the brightness-reversed days.

On the interspersed training trials the shade was used as needed, just as on the overtraining trials. On the test trials the cat was rewarded regardless of the choice made. If the object chosen (i.e., first contacted) happened to be rejected before the experimenter could open the door to the goal box (which took from one to two seconds) the cat was rewarded for contacting or remaining in the vicinity of any object long enough for the door behind it to be opened. Trials of this sort were rather infrequent.

Behavioral observations. Records of the behavior of the animals on each trial were kept, just as in Experiment I. Since it proved impossible to observe, remember, and record accurately all aspects of the animals' behavior on a trial, emphasis was placed upon the approach of the animal to the objects, and upon the correctness of their choices. The precise mode of contact with the objects was recorded as remembered, and only after the mode of approach, and the objects approached and contacted were recorded. Choices were scored as correct or incorrect, depending upon whether the cat first contacted the positive object, or the "correct" test object. The place at which the choice was manifest was ascertained according to the criteria for scoring F, M, and N employed in Experiment I.

Results

Training. The performance of the cats during training is indicated in Table 7. The dependent measures indicated are the number of trials on the discrimination problem (i.e., the odd and correct stimulus object versus the four negative objects), the total number of trials (including all preliminary and later trials in which the positive object was presented alone, plus the discrimination trials), and the number of training days required (1) to demonstrate better-than-chance performance (six correct out of an arbitrarily determined block of ten trials; p = .006), and (2) to reach the performance criterion required before beginning overtraining (fourteen out of the last fifteen trials correct on the first attempt). Also indicated in Table 7 are the number of errors made during overtraining. Mann and Whitney's U was calculated for each score, comparing the hemisphere with the pyramid cats. In no case was a difference significant at the .05 level obtained, which indicates that the two training groups did not differ reliably in terms of the ease with which they learned the discrimination, or their stability of performance during overtraining.

Training trials run on test days. In Table 8 are presented the mean percent correct choices (C+) and correct choices scored F or R (indicated as F' in this table) for each cat in the brightness-normal and brightness-reversed condition. Inspection of the table reveals that, although their choice performance was relatively uniform and quite high, the cats varied considerably in the percent of correct choices made at a distance. In this regard the pyramid cats may have been somewhat more uniform than the hemisphere cats, although the U test reveals no systematic differences between the two groups.

Wilcoxon's T was computed in order to compare the overall brightness-

Table 7

Some Indices of Rapidity of Learning During Experiment II

Positive Training Object	Rat No.	To First Evidence of Discrimination[a]: Trials Discrim. Problem[c]	Total Trials[d]	Sessions	To Criterion[b]: Trials Discrim. Problem	Total Trials	Sessions	Over-training Errors
Smooth hemi-sphere	H14	53	83	5	133	163	7	5
	H31	77	112	6	117	152	7	2
	H32	70	105	6	80	117	6	5
	H34	72	80	3	112	120	4	5
	H36	95	153	8	156	203	9	4
	Mean	73	107	6	120	151	7	4
Rough pyra-mid	F19	33	80	6	63	110	7	1
	F30	49	76	4	99	125	5	5
	F33	53	70	4	83	110	5	2
	F35	98	115	5	168	188	7	2
	F37	70	98	5	120	148	6	6
	Mean	61	88	5	107	136	6	3

a. Six correct on first attempt out of an arbitrary block of ten trials ($p = .006$).

b. Fourteen out of last fifteen trials correct on first attempt.

c. Trials (including criterional trials) run on problem in which correct object is presented with four identical negative objects.

d. Trials (including criterional trials) on discrimination problem, plus all trials in which correct object was presented alone.

Table 8

Mean Percent Correct Choices (C+) and Correct Choices Scored F or R (F') Made by Each Hemisphere-positive and Pyramid-positive Cat under the Brightness-normal and Brightness-reversed Conditions on the Training Trials Run on Test Days in Experiment II

Brightness Condition	Smooth Hemisphere-positive Cats									
	H14		H31		H32		H34		H36	
	C+	F'	C+	F'	C+	F'	C+	F'	C+	F'
Normal	96	79	98	38	98	88	96	37	96	69
Reversed	95	84	97	35	97	91	90	42	97	86

Brightness Condition	Rough Pyramid-positive Cats									
	P19		P30		P33		P35		P37	
	C+	F'	C+	F'	C+	F'	C+	F'	C+	F'
Normal	99	66	98	66	98	62	96	61	97	68
Reversed	99	58	98	66	100	60	94	61	99	71

normal means with the brightness-reversed means. The results indicate no significant differences between brightness conditions for either C' or F' means.

<u>Test</u> <u>results:</u> <u>general</u>. In Appendix A are indicated the number of correct choices made by each cat under each of the test conditions for the brightness-normal situation. The errors made under each condition are indicated in Appendix B. Both correct choices and errors are further broken down according to whether they were scored F, M, or N. Table 9 indicates the number of correct choices, regardless of whether they were scored F, M, or N, made under each of the brightness-reversed conditions.

For the present purposes a property, or a combination of properties, is considered to be effective if (1) a cat makes a total of six or more correct choices (the total possible is ten) under that brightness-normal test condition, and (2) makes three or more correct choices (the total possible is five) under the brightness-reversed condition. Those cases in which criterion (1), but not criterion (2), above was met will be discussed later. Suffice it to say that failure to meet the criterion (2) is at least suggestive that brightness was a factor entering into the success of the animal in meeting criterion (1).*

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*There are several possible means of ruling out brightness as a factor in determining the effectiveness of a given property under the brightness-normal condition, one of which is indicated above. Another approach would regard brightness as a factor that would help the discrimination in the normal condition and hinder it in the reversed condition. In such a case it would be most appropriate to consider the last five brightness-normal tests, together with the five brightness-reversed tests as a unit and determine whether or not statistically significant performance is achieved with the effects of brightness "cancelled out" statistically. When this is done, there is only one case out of the nine critical ones (i.e., the ones in which a property was effective under brightness-normal, but not under brightness-reversed conditions--see Table 10 A or 10 B below) in which the combined scores add up to the criterion of six (the texture test in the negative-

Table 9

Number of Correct Choices Made by Each Hemisphere-positive and Pyramid-positive Cat for Each Context, and for Each Property Tested in the Brightness-reversed Condition in Experiment II[a]

Property Tested	Smooth Hemisphere-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	H14	H31	H32	H34	H36	H14	H31	H32	H34	H36
T	1	1	1	2	3	2	2	2	2	2
O	3	5	5	4	5	4	4	3	3	5
3-D	3	3	3	4	3	2	2	3	4	1
TO	4	4	3	4	4	5	5	4	5	4
T3-D	3	3	2	5	2	2	4	2	5	4
O3-D	5	5	5	5	5	5	5	4	4	5

Property Tested	Rough Pyramid-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	P19	P30	P33	P35	P37	P19	P30	P33	P35	P37
T	3	1	1	1	1	4	4	2	3	5
O	3	1	3	2	2	3	4	4	3	3
3-D	0	2	1	3	2	3	4	5	4	4
TO	3	3	3	2	3	5	4	5	4	5
T3-D	4	3	5	5	3	5	3	5	5	4
O3-D	4	5	4	4	5	5	5	5	5	5

a. Total possible correct = 5.

In Tables 10 A and 10 B are entered the binomial probabilities of chance occurrence for each case* meeting criterion (1). Those cases in which criterion (1), but not criterion (2), was met are designated by "B" following the entry. The probabilities in Table 10 A refer <u>only</u> to the choices scored F or M (i.e., choices manifest at a distance), and the probabilities in Table 10 B refer <u>only</u> to the choices scored N (i.e., choices manifest near the objects). The probabilities indicated in Table 10 A were calculated using ten as the total possible correct. Those in Table 10 B were calculated using ten minus the total number of correct choices scored F or M.** Thus, the cases having entries in Table 10 A are identical with those in Table 10 B, in that only those cases in which six or more correct choices were made were entered. The <u>probabilities</u>, however, are different, since they reflect the distribution of far and near choices among the six or more that were correct in each case. In brief, the <u>presence</u> of an entry in either Table 10 A or Table 10 B indicates for each cat, context, and property tested that that property was effective in the brightness-normal condition, and the presence or absence of "B" indicates whether or not the brightness-normal effectiveness was mitigated by a reversal of brightness relationships.

The essential features of the results presented in Tables 10 A and 10 B are indicated in Figure 5. In this Figure, the positive and negative objects used for each property tested, each context, and each training group (i.e., hemisphere-positive or pyramid-positive) are shown diagrammatically, and the

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unchanged context for H34). These results would appear to support the ruling out of these critical cases on the basis of the brightness scores.

*A "case" is here defined as a given combination involving one cat, one property or property-combination tested, and one context.

**The rationale behind these calculations is the same as that presented on page 42.

Table 10

Binomial Probabilities of Chance Occurrence of Correct Choices Made by Each Hemisphere-positive and Pyramid-positive Cat for Each Context and Each Property Tested in Which Six or More Correct Choices Were Made in the Brightness-normal Condition of Experiment II (Decimals Omitted)

A. Probabilities based upon Choices Scored P and N[a]

Property Tested	Smooth Hemisphere-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	H14	H31	H32	H34	H36	H14	H31	H32	H34	H36
T	[b]	623B[c]							890B	
O	006	120	000	006	006	120		032	032	032
3-D				623						321B
TO	006	321	000	032	000	032	890	321	120	032
T3-D		890	032B	623	321B	120B	890	890B	623	890
O3-D	000	120	000	120	006	000	321	001	623	120

Property Tested	Rough Pyramid-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	P19	P30	P33	P35	P37	P19	P30	P33	P35	P37
T						1000	623	1000B	623	321
O	120					120	032	032		120
3-D				623		890	032	120	006	001
TO	321			006B	321	120	032	006	006	000
T3-D	032	032		032		321	032	623	120	032
O3-D	006	006	120	032	006	120	001	006	006	120

a. For these scores, the total possible correct = 10.

b. No entry means that the cat failed to obtain six or more correct, including choices scored N.

c. "B" following an entry means that, in that condition, fewer than three correct out of five possible choices were made under the brightness-reversed test condition.

Table 10 (continued)

B. Probabilities Based upon Choices Scored N[d]

Property Tested	Smooth Hemisphere-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	H14	H31	H32	H34	H36	H14	H31	H32	H34	H36
T		010B							003B	
O	027	099	1000	181	181	099		059	059	673
3-D				010						010B
TO	181	000	040	007	324	673	000	033	017	007
T3-D		020	264B	001	148B	099B	003	000B	056	000
O3-D	1000	002	1000	000	027	324	005	008	000	000

Property Tested	Rough Pyramid-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	F19	F30	F33	F35	F37	F19	F30	F33	F35	F37
T						006	000	006B	010	148
O	347					002	059	007		017
3-D				010		003	059	002	027	000
TO	005			590B	148	000	027	002	002	200
T3-D	000	059		007		000	000	000	000	007
O3-D	181	590	017	264	590	000	104	027	027	000

d. For these scores, the total possible correct = 10 − $N_{F'}$, where $N_{F'}$ is the number correct scored F or N. See text for explanation.

Figure 5. Illustration of Test Situations Used in Single and Combined-property Tests, and Summary of Results Obtained for Hemisphere-positive and Pyramid-positive Cats.

Explanation of figures: Outline of test objects indicated by shape of borders of figures (square or circular). "Pyramidal" three-dimensional shape indicated by internal squares and diagonal lines. "Hemispherical" three-dimensional shape indicated by absence of internal squares, etc. Texture indicated by "R" (rough) or "S" (smooth) immediately below figure. In each array the center figure (+) represents the odd and correct object.

Explanation of results: "Effective" means that the number of cats indicated chose the test object (+) six or more times in the brightness-normal condition <u>and</u> three or more times in the brightness-reversed condition. "Not effective" means that all cats failed to achieve one or both of these criteria. "Near" and/or "far" indicate that, considering as a group all cats for whom the property was effective, a greater than chance ($p < .05$) number of correct choices were scored F or F (far) and/or N (near) under that condition.

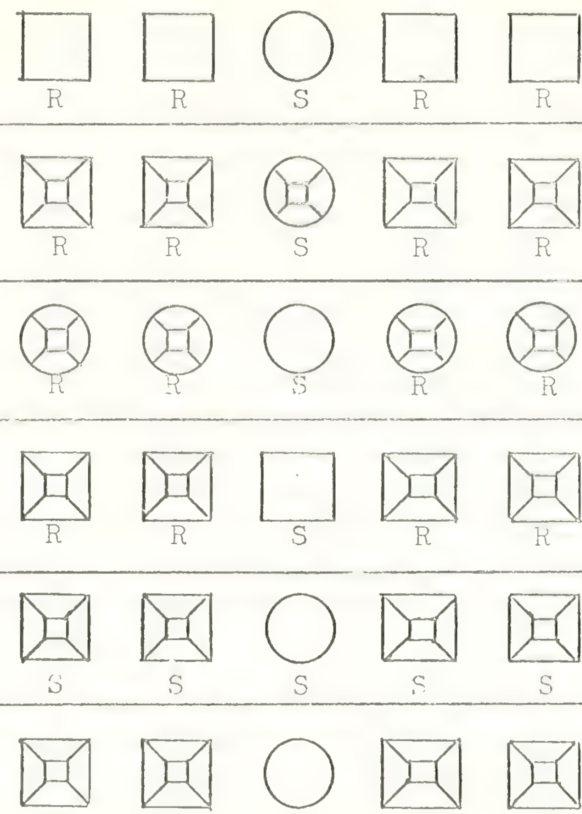
Figure 5

a. Smooth Hemisphere-positive Cats: Single Property Tests

Property Tested	Context	Test Situation -	Test Situation -	Test Situation +	Test Situation -	Test Situation -	Results
Texture	Positive-unchanged	R	R	S	R	R	Not effective
	Negative-unchanged	R	R	S	R	R	Not effective
Outline	Positive-unchanged	S	S	S	S	S	Effective for 5 of 5 cats (far and near)
	Negative-unchanged	R	R	R	R	R	Effective for 4 of 5 cats (far and near)
3-D Shape	Positive-unchanged	S	S	S	S	S	Effective for 1 of 5 cats (near only)
	Negative-unchanged	R	R	R	R	R	Not effective

Figure 5 (continued)

b. Smooth Hemisphere-positive Cats: Combined Properties Tests



Property Tested	Context	Test Situation −	−	+	−	−	Results
Texture plus Outline	Positive-unchanged	R	R	S	R	R	Effective for 5 of 5 cats (far and near)
	Negative-unchanged	R	R	S	R	R	Effective for 5 of 5 cats (far and near)
Texture plus 3-D Shape	Positive-unchanged	R	R	S	R	R	Effective for 2 of 5 cats (near only)
	Negative-unchanged	R	R	S	R	R	Effective for 3 of 5 cats (near only)
Outline plus 3-D Shape	Positive-unchanged	S	S	S	S	S	Effective for 5 of 5 cats (far and near)
	Negative-unchanged	R	R	R	R	R	Effective for 5 of 5 cats (far and near)

Figure 5 (continued)

c. Rough Pyramid-positive Cats: Single Property Tests

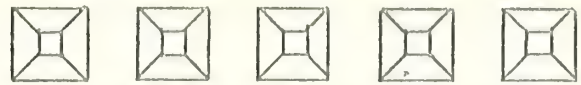
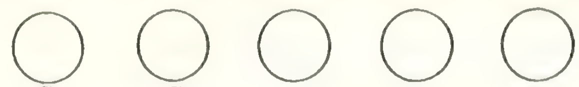
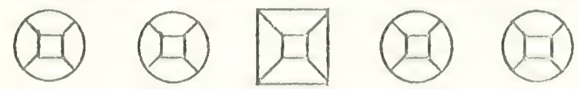
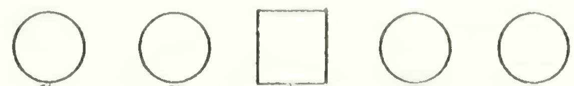
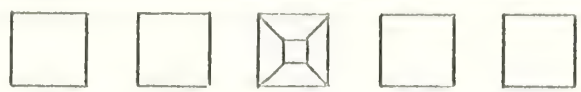
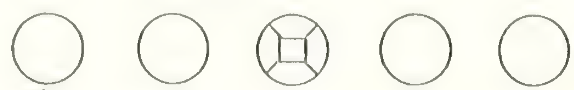
Property Tested	Context	Test Situation -	-	+	-	-	Results
Texture	Positive-unchanged	 S	S	R	S	S	Not effective
	Negative-unchanged	 S	S	R	S	S	Effective for 4 of 5 cats (near only)
Outline	Positive-unchanged	 R	R	R	R	R	Effective for 1 of 5 cats (place ambiguous)
	Negative-unchanged	 S	S	S	S	S	Effective for 4 of 5 cats (far and near)
3-D Shape	Positive-unchanged	 R	R	R	R	R	Effective for 1 of 5 cats (near only)
	Negative-unchanged	 S	S	S	S	S	Effective for 5 of 5 cats (far and near)

Figure 5 (continued)

d. Rough Pyramid-positive Cats: Combined Properties Tests

Property Tested	Context	Test Situation -	-	+	-	-	Results
Texture plus Outline	Positive-unchanged	S	S	R	S	S	Effective for 2 of 5 cats (near only)
	Negative-unchanged	S	S	R	S	S	Effective for 5 of 5 cats (far and near)
Texture plus 3-D Shape	Positive-unchanged	S	S	R	S	S	Effective for 3 of 5 cats (far and near)
	Negative-unchanged	S	S	R	S	S	Effective for 5 of 5 cats (far and near)
Outline plus 3-D Shape	Positive-unchanged	R	R	R	R	R	Effective for 5 of 5 cats (far only)
	Negative-unchanged	S	S	S	S	S	Effective for 5 of 5 cats (far and near)

number of cats for whom each test condition was effective in <u>both</u> brightness-normal <u>and</u> brightness-reversed tests is indicated.

The data presented in Tables 10 A and 10 B and in Figure 5 are described below. First of all, the overall (i.e., without regard to place at which choice is made) effectiveness of each single property and property-combination not affected by brightness-reversal will be indicated. Next, the data indicating the place at which the choice was made will be described, and then the cases in which effectiveness of a property or property combination was mitigated by brightness-reversal will be considered.

<u>Texture</u>. Inspection of Table 10 A or 10 B, or of Figure 5, reveals that if the entries marked "B" are ruled out, none of the <u>hemisphere</u> <u>cats</u> chose on the basis of texture differences alone. They would choose neither a smooth hemisphere in preference to four rough hemispheres (the positive-unchanged context), nor a smooth pyramid in preference to four rough pyramids (the negative-unchanged context). On the other hand, four of the five <u>pyramid</u> <u>cats</u> chose correctly on the basis of texture when the test required the selection of a rough hemisphere from four smooth hemispheres (negative-unchanged), but not when a rough pyramid was to be picked out from four smooth pyramids (positive-unchanged).

<u>Outline</u>. When the tests involved outline differences only, all five of the <u>hemisphere</u> cats would choose a smooth hemisphere with a circular base rather than a smooth "hemisphere" with a square base (positive-unchanged), and four of the five would choose a rough "pyramid" with a circular base in preference to a rough pyramid with a square base (negative-unchanged). However, among the <u>pyramid</u> cats only one would select a rough pyramid with a square base in preference to four rough "pyramids" with circular bases (positive-unchanged). Four out of the five would, on the other hand, choose a smooth "hemisphere"

with a square base in preference to a smooth, circular-based hemisphere (negative-unchanged).

Three-dimensional shape. When the objects differed only in three-dimensional shape, only one hemisphere cat would choose the correct object, and then only when it was a smooth hemisphere, presented in the context of four smooth "pyramids" with circular bases (positive-unchanged). In a like manner, only one pyramid cat would choose a rough pyramid presented with four rough "hemispheres" with square bases (positive-unchanged). However, all five pyramid cats would select a smooth "pyramid" with circular base in preference to four smooth, circular-based hemispheres (negative-unchanged).

Combined properties. When the tests in which properties are combined are considered, it is seen that all hemisphere cats would choose a test object when it had a circular base and the four 'negative' objects had square bases (all combinations involving outline; both positive- and negative-unchanged contexts). Only two hemisphere cats, however, would choose a smooth hemisphere in preference to a rough "pyramid" with a circular base (texture-three-dimensional shape combination; positive-unchanged context). On the other hand, three of the hemisphere cats would choose a smooth "hemisphere" with a square base in preference to a rough pyramid with a square base (texture-three-dimensional shape combination; negative-unchanged context).

In the case of the pyramid-trained cats, only two cats would choose a rough, circular-based "pyramid" in preference to a smooth, square-based pyramid (texture-outline combination; positive-unchanged context), whereas all five cats would choose a rough, square-based "hemisphere" in preference to a smooth, circular-based hemisphere (texture-outline combination; negative-unchanged context). When the correct object was a rough pyramid and the incorrect objects were smooth and rounded, with all objects having square bases,

only three pyramid cats would choose the correct object (texture-three-dimensional shape combination; positive-unchanged context). When the bases were circular, however, all five pyramid cats would choose the correct object (texture-three-dimensional shape combination; positive-unchanged context). Finally, all five cats would choose a square-based pyramid in preference to a circular-based hemisphere, regardless of the texture of the objects (outline-three-dimensional shape combination; positive- and negative-unchanged contexts).

<u>The position at which the choice is manifest</u>. In order to uncover any relationship between the nature of the effective properties and the place at which the correct choice was made, Fisher's (1950) Chi-square method for combining probabilities was applied to the data in Tables 10 A and 10 B. The combined-probabilities for every quality tested in which two or more cats had entries (exclusive of the entries marked "B") were computed. The results are indicated in Table 11 and again in Figure 5, p. 66.

Far choices: Considering only the choices made at a distance (F'), it is apparent that for the <u>hemisphere cats</u>, only those tests involving outline differences elicited a greater-than-chance ($p < .05$) number of correct choices. The texture-three-dimensional shape combination was ineffective at a distance in both the positive- and the negative-unchanged contexts. For the <u>pyramid</u> cats, on the other hand, all properties and combinations tested, except for texture, were effective at a distance in the negative-unchanged context. In the positive-unchanged context both property-combinations involving three-dimensional shape differences were effective, whereas the texture-outline combination was not.

Near choices: Considering the choices made near the objects, it can be seen that in only one case--that of the <u>pyramid cats</u> tested in the outline-

Table 11

Combined Probabilities Chi-square Values for Far and Near Choices for Hemisphere-positive and Pyramid-positive Cats, for Each Context and Each Property Tested in Which Two or More Cats Scored Six or More Correct and Were Unaffected by Brightness Reversal in Experiment II

Property Tested	Smooth Hemisphere-positive Cats							
	Far Choices				Near Choices			
	Positive-unchanged Context		Negative-unchanged Context		Positive-unchanged Context		Negative-unchanged Context	
	df	χ^2	df	χ^2	df	χ^2	df	χ^2
T O 3-D	10	48.9***	8	24.9**	10	18.7*	8	16.7*
TO	10	47.4***	10	20.5*	10	36.0***	10	39.7***
T3-D	4	1.2	6	1.4	4	21.6***	6	31.4***
O3-D	10	46.7***	10	35.3***	10	33.7***	10	50.9***

Property Tested	Rough Pyramid-positive Cats							
	Far Choices				Near Choices			
	Positive-unchanged Context		Negative-unchanged Context		Positive-unchanged Context		Negative-unchanged Context	
	df	χ^2	df	χ^2	df	χ^2	df	χ^2
T			8	4.2			8	37.3***
O			8	22.2**			8	36.2***
3-D			10	35.6***			10	46.6***
TO	4	4.5	10	45.6***	4	14.4**	10	49.3***
T3-D	6	20.7**	10	21.2*	6	25.6***	10	65.3***
O3-D	10	41.8***	10	42.8***	10	16.3	10	47.0***

* $p < .05$.

** $p < .01$.

*** $p < .001$.

three-dimensional shape combination in the positive-unchanged condition (i.e., where all objects were rough in texture), was there a failure to make a greater-than-chance number of choices.

The single cases not included in the analysis presented in Table 11 are not numerous. H34 would choose on the basis of three-dimensional shape when the outline and texture of all objects were positive, but only in the near situation ($p = .010$ for near; $p = .623$ for far). Precisely the same situation holds for P35. The data for P19, however, are inconclusive. When outline differences were tested in a context of the positive texture and three-dimensional shape, neither far nor near choices exceeded the .05 level of confidence ($p = .120$ for far; $p = .347$ for near).

The effects of brightness reversal. Further examination of Tables 10 A and 10 B, pp. 63 and 64, reveals the following with regard to the entries marked "B". In the first place, there were seven such cases for the hemisphere cats (and every cat was affected in at least one test condition), whereas for the pyramid cats, there were only two such cases. This would indicate that role of brightness was greater for the hemisphere cats. Secondly, all of the affected hemisphere cases consisted of tests involving texture and/or three-dimensional shape differences. One of the pyramid cat cases involved the test for texture, and the other involved the texture-outline combination. Thirdly, it appears that for these same cases in the brightness-normal condition, the correct choices were made predominantly near the objects. This conclusion is based upon the fact that, with two exceptions, the binomial probabilities are smaller for the near choices than for the far choices. (One of the two exceptions is H32, in which the texture-three-dimensional shape combination in the positive-unchanged condition was affected—$p = .032$ for far; $p = .264$ for near. The other exception was P35,

for whom the texture-outline combination in the positive-unchanged context was affected—$p = .006$ for far; $p = .590$ for near).

<u>The distribution and position of incorrect choices</u>. For the purposes of analysis of the errors made on the test trials, Table 12 was prepared. In this table are indicated the percent incorrect choices scored F or M for each case not entered in Table 10 A and 10 B. (I.e., for every entry in Table 12, five or more errors were made.) It is apparent that for the <u>hemisphere</u> cats the majority of erroneous choices made under the positive-unchanged conditions were made at a distance ($p = .04$, by two-tailed sign test), whereas those made in the negative-unchanged conditions were made in the vicinity of the objects ($p = .016$, excluding zero percents, which are meaningless in this context, since, in these cases, <u>all</u> incorrect choices were made at a distance). Similarly, the <u>pyramid</u> cats tended to make more errors at a distance in the positive-unchanged conditions. For these cats, there was only one out of seventeen cases in which fewer than fifty percent of the errors were scored F or M ($p < .001$). The only pyramid cat entered under the negative-unchanged condition was P35, who failed in the test for outline. This cat made 33 percent of its errors at a distance.

<u>The effect of combining trials scored M with those scored F</u>. In the analysis thus far, choices scored F and choices scored M were both taken to indicate choices made "at a distance." The M's were included in the distance-choice category for two reasons: (1) It appeared desirable to distinguish choices that were clearly manifest in the immediate vicinity of the objects from those that were manifest at some other place. (2) There were too few M-choices to warrant including them in a separate category of choices. Consequently, they were combined with the F choices and called "distance-choices." This rationale may or may not be justifiable. However, inspection of

Table 12

Percent of Total Errors Scored F or [illegible], for Each Hemisphere-positive and Pyramid-positive Cat, Each Context, and Each Property Tested when Five or More Errors Were Made under the Brightness-normal Condition in Experiment II

Property Tested	Smooth Hemisphere-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	H14	H31	H32	H34	H36	H14	H31	H32	H34	H36
T	100		88	43	90	33	00	33		17
O							00			
3-D	100	60	100		88	40	20	43	17	
TO										
T3-D	67									
O3-D										

Property Tested	Rough Pyramid-positive Cats									
	Positive-unchanged Context					Negative-unchanged Context				
	P19	P30	P33	P35	P37	P19	P30	P33	P35	P37
T	50	67	50	100	100					
O		60	33	100	100				33	
3-D	50	100	56		88					
TO		50	100							
T3-D			60		100					
O3-D										

Appendixes [illegible] and [illegible] reveals the relative paucity of [illegible]-choices, compared with F's and N's, which, in turn, suggests that the combining of [illegible]'s with F's as distance choices would have little effect upon the results as presented here.

<u>The results in summary form</u>. Hemisphere cats: For the hemisphere cats, only outline differences were generally effective at a <u>distance</u>. In the <u>near</u> situation, outline was again effective, as was three-dimensional shape for one cat. The texture-three-dimensional shape combination was effective, but only for two cats in the positive-unchanged condition, and for three cats in the negative-unchanged condition. In all other cases where texture or three-dimensional shape differences were effective, the effectiveness was mitigated by reversing the brightness relationship between positive and negative objects.

Pyramid cats: For the pyramid cats, outline and three-dimensional shape differences were effective in the <u>far</u> situation, but only, when tested singly, in the negative-unchanged condition. When presented in combination, they were effective in both positive and negative-unchanged conditions. In the <u>near</u> situation, all properties tested were effective in the negative-unchanged condition. The effectiveness of the property-combinations tested in the positive-unchanged condition varied from cat to cat. However, the outline-three-dimensional shape combination was generally not effective under this condition.

Discussion

<u>Comparison with Experiment I: the negative-unchanged context</u>. The results of this experiment tend to confirm those obtained in the previous experiment. Considering only the negative-unchanged context, which is the only con-

dition with respect to which the two experiments are comparable, it is seen that in both experiments the pyramid cats tended to choose on the basis of all three of the single properties: texture, outline, and three-dimensional shape, whereas the only effective property for the hemisphere cats was outline. Moreover, the relationship between effective properties and the place at which choice was manifest was confirmed, in that texture, when effective, was effective only in the near situation, whereas outline and three-dimensional shape were, in a number of cases, effective in the far situation, as well as in the near situation.

<u>The positive-unchanged context</u>. It was suggested on the basis of the results of Experiment I which indicated that only outline was effective for the hemisphere cats, whereas texture, outline, and three-dimensional shape were effective for the pyramid cats, that the introduction of the positive-unchanged condition would increase the effectiveness for the hemisphere cats of properties tested singly. This suggestion was not confirmed by the results of Experiment II. Indeed, the most apparent effect of the introduction of the positive-unchanged context was a <u>reduction</u>, for the <u>pyramid cats</u>, of the apparent effectiveness of all three properties tested singly. This effect, on the other hand, was not seen in the case of the hemisphere cats. This finding is quite interesting, and some explanation for it would appear to be required.

If the effectiveness of all the single properties as demonstrated in the negative-unchanged context can be assumed, then one possible explanation for the ineffectiveness of single properties in the positive-unchanged context for the pyramid cats, but not for the hemisphere cats, presents itself. This explanation would involve the assumption that the cats were reacting positively to any object having (effective) positive features, without regard for

its negative features. If this is true, then, in such a case as that of the test run in the positive context, in which all objects had some positive features, the distribution of choices among the objects would tend toward chance, which is exactly what happened. The failure for this phenomenon to be manifest in the hemisphere cats would appear to reflect the relative lack of effectiveness of texture and three-dimensional shape. Thus, if only outline were effective, then its effectiveness could not possibly be mitigated by the presence of any other (ineffective) feature of the positive object.

At least two other features of the data support this hypothesis. The fact that a majority of the incorrect choices made by the pyramid cats in the ineffective positive-unchanged conditions were manifest at a distance suggests that the animals were, on a number of these trials, reacting to one of the two untested properties, outline or three-dimensional shape, which were shown in the negative context to be effective at a distance. Furthermore, the ineffectiveness of the positive-unchanged outline-three-dimensional shape combination for near choices for these cats also supports this hypothesis. Thus, if, for some reason, a correct choice were not made at a distance, the cats may have tended to make near choices on the basis of texture, in which all five objects were positive. (On the other hand, the support given by this datum is relatively weak, since there were only a small number of possible correct choices in that situation, due to the dominance of distance choices. Consequently, the statistical tests would appear to provide less reliable indices of significance.)

It should be noted that the present hypothesis is contrary to one point of view (e.g., Spence, 1937) which suggests a gradient of inhibition around the negative stimulus. The present results are interpreted to mean that the features of the negative objects play a relatively minor role in the

present experimental situation. Whether the same would hold true if only two objects, rather than five objects, would be presented cannot of course be answered here. It should, however, be pointed out that both Maier (1939) and Kissen and Jenkins (1943) suggest that the properties of the positive training stimulus (Maier used patterns, Kissen and Jenkins objects) are dominant in two-choice discrimination situations. These experiments will be discussed in more detail in the following section.

DISCUSSION

In this section emphasis will be placed upon the results of Experiment II. The three major reasons for this emphasis are: (1) the testing was more thorough in Experiment II, in that the positive-unchanged, as well as the negative-unchanged context, was employed, and additional tests were introduced to allow for the assessment of the role of brightness differences; (2) a larger number of cats were run in Experiment II; (3) the training and testing conditions were more nearly standard for all cats in Experiment II. On the other hand, data from Experiment I will be discussed when it has a bearing upon the argument to be presented.

The discussion is divided into five parts. In the first part, the properties of the stimulus objects will be reconsidered from the point of view of their projection upon the retina of the cat at the time of choices made at a distance and near the objects. In the second part, certain similarities between the results of the present experiment and results published by others, using other animals as subjects, will be discussed. In the third part, a tentative, ad hoc explanation of the findings will be offered. Here some additional observational data from the present study and the findings of an independent experiment by the writer will be introduced in support of the explanation. In the fourth part the implications of the present findings and of the explanation offered for them for the comparative study of perceptual processes

and the relationship of these processes to some general comparative neurological considerations will be discussed. In the fifth part comments will be made apropos of some methodological considerations arising in the present study.

The Retinal Representation of the Training Stimulus-objects

The purpose of this section is to indicate what are presumably the features of the retinal images of the training objects in the situation in which a choice was scored [illegible] or [illegible] (hereafter called the "far situation"), and in the situation in which a choice was scored [illegible] (hereafter called the "near situation"). The aim is to provide a context suitable for relating the present results to those of previous experiments and to the operation of hypothetical selective properties.

Rough pyramid. For a stationary object and eye in the far situation* the outline of the rough pyramid is represented retinally by a pattern of brightness contrasts, in which an enclosed light area is surrounded by a darker background. It is clear that, so considered, a basic property of the object is its relationship to the background, and that this is equivalent to the figure-ground relationship in two-dimensional stimulus patterns. (Shape as defined by these enclosing contrasts will be considered as an "external" or "border" feature of the retinal image of the object. Features of the image of the objects within this enclosed area will be called "internal" features.)

The three-dimensional shape of the pyramid, on the other hand, is

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*It should be pointed out that binocular effects are ignored in this section. Consideration of them would, however, not appreciably change the conclusions drawn on the basis of this analysis.

represented in the far situation by internal features, consisting of one square and four trapezoidal areas differing in brightness, as a result of the different dispositions in space of the five front surfaces of the pyramid in relation to the sources of illumination. The junctions of these internal zones constitute relatively sharp borders, although the texture of the objects serves to diminish this sharpness. Other internal features consist in an unsystematic distribution of small darker and lighter areas throughout the enclosed light area, due to the texture of the surface of the pyramids. Since the animal is relatively constricted in the detention box, the range of variation in the retinal images of the objects is not very great.

In the near situation, on the other hand, the position of the animal relative to any particular object, and, concomitantly, the retinal image of the object, is considerably more variable, since the animal may take any of a large number of positions relative to the array of objects. Thus, unless the object is viewed from directly in front, the pyramidal three-dimensional shape would be represented by border, or external, features as well as by internal features. The relative contribution of the outline of the base to the border features would vary inversely with the contribution of three-dimensional shape. Three-dimensional shape would, however, always be represented by some internal features, since the object could never be viewed directly from its side. The surface texture is represented as mostly internal features, although it has an effect upon external features as well, since the edges of the pyramid are necessarily somewhat irregular.

Smooth hemisphere. Considering next the retinal image of the smooth hemisphere, it would appear that in the far situation, outline shape is represented by border features, characterized by relatively strong brightness contrasts. Its three-dimensional shape, on the other hand, is represented by a

two-dimensional gradient of brightness, with no sharp separation of brightness zones. The smoothness of the surface is, of course, characterized by relative uniformity and the absence of the irregularly distributed internal brighter and darker areas present in the image of the pyramid.

In the near situation both outline and three-dimensional shape are represented as border features. Three-dimensional shape is also represented as a two-dimensional brightness gradient, as an internal feature of the image. The smoothness of the surface is again characterized by uniformity and the absence of the irregular pattern of internal contrasts seen in the rough pyramid.

One further feature of the near situation is that either object must frequently be seen against a background which partially (i.e., on one or both sides) consists of the other objects that are displayed. In such a case, the conjunction of the images from the two adjacent objects would eliminate some of the strong external brightness contrasts separating object from ground. Not eliminated, however, are the "intrinsic" brightness differences between the hemispheres and the pyramids, due to the texture and three-dimensional shape differences.

The effectiveness of retinal image properties. The data obtained in the present experiment may now be reinterpreted in terms of the (hypothetically) effective features of the retinal images of the objects. It would seem that external, or border features are effective for both hemisphere and pyramid cats. This hypothesis is drawn primarily from the effectiveness of outline in the far situation and in the near situation. The effectiveness of three-dimensional shape in the near situation, in which this property is represented in part externally, would tend to support this hypothesis, although without very much certainty, due to the fact that three-

dimensional shape is also represented by internal features in the near situation.

On the other hand, it would appear that <u>internal</u> features of the objects were effective only for the pyramid cats. This contention is based upon (1) the effectiveness of three-dimensional shape alone in the far situation for the pyramid, but not for the hemisphere cats, and (2) the effectiveness of texture in the near situation for the pyramid but not for the hemisphere cats. An additional feature of the results supporting this contention is seen in the scores obtained in the brightness-reversed condition. The hemisphere cats appeared to be considerably more affected by this reversal than the pyramid cats. It is not difficult to conceive of overall brightness as an object-property that "functions" predominantly at the border of the object, at least in the near situation, where the brighter (or darker) object frequently is seen against a background consisting of other objects of a different brightness. (I.e., the brightness differences would tend to "set off" the odd object from the adjacent ones.) Most of the correct choices that were made by the hemisphere cats on those brightness-normal test conditions whose effectiveness proved to be mitigated by brightness reversal, were made in the near situation. Thus, it is not unreasonable to conclude that, in the brightness-normal condition, the effectiveness of texture and three-dimensional shape (in those few cases in which they <u>were</u> effective) involved these subtle brightness differences, which served as border features of the objects.

Relation of Present Results to Results of Other Experiments

Three features of the present results appear to be at least partly relatable to the results of studies using other animals as subjects. The first

concerns the role of outline, or shape as defined by border brightness contrasts, as an effective stimulus object property. The second feature is the effect of the context in which the test objects are presented, and the third concerns the differences in effectiveness of certain properties as a function of which object was positive.

The role of outline. Considering the results of hemisphere and pyramid cats together, it would appear that outline shape is the only feature of the stimulus objects that was "generally" effective--that is, that was effective for at least one context for most of the cats. If this can be interpreted as indicating the functional superiority of information carried by the borders of the objects, then the results are similar to those reported by Warren (1953c) and by Riopelle, Wunderlich, and Francisco (1958). These authors, it will be recalled, reported that performance on color discrimination tasks was better if the differentiating color was located at the border of the object or card than if it was located in the center.

Lashley (1938) has reported that, in the case of the rat, external features of the discriminanda tend to dominate, although the effect is also a function of the relative conspicuousness of the internal figure. He also infers from his data that rats rarely react to the total figure, tending instead to form part-figures. In this regard he indicates that "The most important factor in defining the part-figure is the relation of the stimulus card to the surrounding frame." (p. 152) It would appear that, if one considers the stimulus pattern, the card, and the frame as a "stimulus-unit," relatively external features of the "stimulus-unit" are dominant in the rat as well.

The role of the context in which tests are run. It will be recalled that in Experiment II the pyramid cats exhibited an apparent lack of effec-

tiveness of all properties tested singly when the tests were run in a situation in which the unchanged positive training object served as the odd and correct object, and was presented along with four identical negative objects having some positive and some negative properties. These same properties, however, when tested in a context in which the four identical negative training objects were unchanged, the odd and correct object having both positive and negative properties, were quite effective. Similar results have been reported by Nissen and Jenkins (1943). These investigators used chimpanzees as subjects in an experiment, the design of which was essentially the same as that of Experiment II. The animals were trained in a two-choice situation to discriminate objects differing in "color" (black vs. white) and size. They next ran tests for the relative effectiveness of each property under both positive-unchanged and negative-unchanged conditions. They found that transfer, regardless of the property tested, was better under the negative-unchanged condition. Their explanation for this finding was similar to that offered above for the findings of the present experiment--i.e., that the animals were reacting primarily to properties of the positive object.

The effect of the positive training object. The present experiment also demonstrated that the effectiveness of features of the object represented in the retinal image as "internal" features were differentially effective for the hemisphere-positive and pyramid-positive cats. If these results are attributable to the fact that the positive and/or negative object was different for the two groups, then they are somewhat similar to the results of two earlier experiments, both of which used rats as subjects. Chang (1936; cited by Nissen and Jenkins, 1943) trained rats to discriminate two-dimensional stimulus patterns differing in form and size. He found that rats trained to choose the larger of the two patterns tended to respond on the basis of size,

whereas rats trained to choose the smaller pattern tended to respond on the basis of form. Later Maier (1939) also reported that rats made different equivalence reactions in a two-choice situation, depending upon which of the two stimulus cards was made positive. When rats were trained to discriminate a black circle on a white background from a white circle of the same size on a black background the rats for whom the black circle was positive (this card was also the brighter, due to the greater total amount of white on the card) tended to react on the basis of the "absolute properties" of the positive card. A second group of rats was trained to discriminate a large black circle from a small black circle, each presented on a gray background. Those rats trained to choose the larger circle tended to respond on the basis of size, whereas those trained to choose the smaller circle chose predominantly on the basis of brightness. He concludes that the "absolute properties of the positive stimulus card are important determiners of what is learned, whereas the absolute properties of the negative stimulus are relatively unimportant." (1939, p. 324)

The present findings are in partial accord with Maier's findings. However, for the cats in the present study, there was no indication that the situation was the "either . . . or . . ." type. (I.e., it did not appear to be the case that <u>either</u> external features <u>or</u> internal features, but <u>not both</u>, were effective.) External features were generally effective for both groups. On the other hand, the differential effect of the brightness-reversed conditions may be more nearly consonant with Maier's findings. Thus, in individual cases where texture and/or three-dimensional shape were effective, the hemisphere cats showed more "failures" under the brightness-reversed condition than the pyramid cats. Since the smooth hemisphere was, overall, the brighter of the two objects, it may be the case that, where the brighter object was

positive, the reaction tended to be made more on the basis of brightness than when the darker object was positive. As will be implied in the discussion to follow, this explanation is not favored. It is sufficient to indicate in the present context that both Chang's and Maier's studies, as well as the present one, point to differences in what is learned as a function of the object that is positive. The qualitative nature of the differences discovered do not appear to be comparable on the basis of the data reported here.

A Tentative Explanation of the Findings

The two major aspects of the results thus far presented are (1) the general effectiveness of outline shape, or, of object properties represented retinally as border features of the image of the object, and (2) the limited effectiveness of three-dimensional shape (as tested here) and texture, or, of object properties represented retinally as internal features of the image of the object. The first finding is not very surprising, since it has been demonstrated by a number of other investigators. The second finding, however, that the properties that are effective are a function of which object is positive, is somewhat surprising, although, as indicated above, it has been reported as a <u>general</u> finding by other investigators. What is most unexpected is the relative strength of effectiveness of internal features, in that they appeared to interfere considerably with the demonstration of effectiveness of external features under certain conditions. On the basis of the literature reported here, one would have expected the external features to dominate, which was apparently not the case for the pyramid-trained cats.

Surprising or not, both findings would appear to require explanation. To consider the problem anthropomorphically, it would be instructive to de-

termine why "squareness," "roughness," and "projecting angularity" (for lack of a better phenomenological description of the three-dimensional shape of the pyramid) were all important features of the pyramid for the pyramid-trained cats, whereas only "circularity," but not "smoothness" or "uniform roundedness" were important features of the hemispheres for the hemisphere cats.

As a means to a possible explanation of the differential effectiveness of the internal features, it may be fruitful to consider three additional aspects of the stimulus situation. One aspect is related to the fact that both object and cat are moving. The second is related to the fact that a considerable amount of tactual information about the objects was available at all stages of training. The third involves differences in stimulation for changes in accommodation produced by the two objects.

The motion of cat and object has a definite effect on the retinal image of the objects. Complex, but regular, transformations of the retinal image occur whenever movement occurs. The nature of these transformations has been discussed in detail by Gibson (1951, 1958), who considers them to be the "adequate stimuli" for a number of visually guided reactions of animals (1958). It is of particular interest here to point out that movement-produced changes of the image of the pyramid are somewhat greater than changes in the image of the hemisphere. For the pyramid, "internal" features may be transformed into "border" features; the number of sides of the border changes from a minimum of four to a maximum of six; the outline shape of the image changes along with the change in "elements" constituting the borders, and the shape of the internal brightness zones changes. Furthermore, the angular size of the texture units increases, and, at some point between the detention box and the object display, reaches "threshold" size for effectiveness, judging from the effectiveness of texture only in the near situation. Of these changes, the

only one that would appear to take place in the case of the hemisphere is the change in outline shape. This change, however, is only from circular to ellipsoidal. If amount of change be regarded as an index of the amount of stimulation produced by the changing image, then approaching a pyramid would appear to be more stimulating than approaching a hemisphere.

Considering the two kinds of movement (i.e., of the cat and of the object), it would appear that movement of the objects can be ruled out as an essential factor on the basis of some additional findings. The pyramid cats of Experiment I were given additional tests (not reported previously) in which none of the objects were moving. Although these tests were administered somewhat unsystematically, the results suggested that absence of object movement did not disrupt the animals' performance at all on any of the tests in which previously effective properties were tested.

The tactual features of the objects are, of course, also different. The consequences of contact with a rough pyramid are presumably more "differentiated," more "salient," or, in general, more "stimulating" than the consequences of contact with a smooth hemisphere. Compared to the pyramid, the hemisphere may be classed as somewhat of a tactual Ganzfeld, in that no corners, edges, or rough spots are present to differentiate any part of it from any other part.

As an additional feature of the situation, interaction with the pyramid, particularly in the near situation, would appear to provide the basis for changes in accommodation of the lens, both because of the texture of the surface, which varies in depth, and the existence of edges at different distances from the eye. On the other hand, these same changes would be minimal in the case of the hemisphere.

It is tempting to speculate that some one, two, or three of the above features of the stimulus situation are responsible for the effectiveness of internal features of the objects for the pyramid cats and their ineffectiveness for the hemisphere cats. It is suggested that visual "roughness," or "projecting angularity," was important for the pyramid cats and "smoothness," or "uniform roundedness," not important for the hemisphere cats because interaction with a rough, angular object (active movement towards it, contact with it, or inspecting different "levels" of it) which, for the pyramid cats, resulted in reward, also resulted in a relatively differentiated sensory consequence. On the other hand, interaction with a smooth or rounded object (which led equally to reward for the hemisphere cats) resulted in a relatively "undifferentiated" sensory consequence.

To put the matter somewhat differently, it is proposed that the visual effectiveness of properties other than simple border characteristics requires or, at least, tends to require, in a situation in which both border and internal features are present, active intercourse with the object, which may be called perceptual behavior. Furthermore, it is proposed that this perceptual behavior must result in a "sufficiently large" change in stimulation.

It is difficult to say at present whether all of the types of change suggested above are required, although it would be possible to clarify the matter in future experiments. Nevertheless, there is some evidence that the visual changes may not be sufficient by themselves, and that the tactual consequences of contact with the object are quite important.

During the early stages of training, contact with the objects was a dominant feature of the behavior of all cats. This contact appeared to be "exploratory" in nature--i.e., characterized by active rubbing of the objects

with a paw and/or with the nose or vibrissae.* The active, exploratory aspects of the contact appeared to drop out more for certain of the animals and less for others. Indeed, for certain of the animals, the contact response gradually degenerated into a mere gesture in the direction of the object, or even into merely standing in front of the object chosen. Among those animals whose contact response degenerated, the degree of degeneration appeared to be somewhat less for the pyramid than for the hemisphere cats. The most prominent degeneration occurred in animals H3 and H7 of Experiment I, and animals H14 and H32 of Experiment II, all of whom were trained to choose the hemisphere. H31 and H36 showed less degeneration, and did not appear to be very different in this respect from P4 (Experiment I), P38, and perhaps P37. Of the hemisphere cats, H34 showed the least degeneration. The remainder of the pyramid cats--P8 and P12 (Experiment I), and P19, P33, and P35 showed varying degrees of rubbing, but, in general, more than the rest of the cats. The pyramid cats thus tended to behave more vigorously in relation to the objects than the hemisphere cats, and, the inference from this is that contact played a more important role in the situation for these cats than for the hemisphere cats. It is suggested that the role of contact may be related to those properties of the object which were effective for the various cats.

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*The above statements are subject to a number of criticisms, not the least of which is that they reflect the "general impression" of the experimenter, rather than a careful analysis of notes made at the time the behavior was observed. The reason for this was that E found himself quite prone to forget certain details of the cats' behavior on a given trial while he was recording other details. In order that he not forget the essential features of the cats' approach behavior, he found it necessary to record this aspect first, at the expense of certainty of accuracy in description of the mode of contact with the objects. The impression that the statements reflect, however, is quite strong, and probably not too far removed from what actually happened.

There is additional evidence from an experiment by the writer* that contact is an important feature in visual object-discrimination in the cat. Two female cats, Nos. 97 and 156, were trained in a two-choice discrimination box to discriminate a wedge (base = 2 inches square; height = 1-1/2 inches) from a rectangular solid (base = 2 inches square; height = 3/4 inch square). The objects were painted a medium gray and their bases glued to black cards, which were, in turn, fastened to the doors of the discrimination apparatus. The cats' task was to push the door containing the correct object, thus gaining access to a morsel of horse meat. The incorrect door was locked. During most of the experiment the doors were approximately ten inches from the choice point. The front edge of the wedge was presented vertically. Thus, the outline shapes of the objects were identical, the only difference being in "three-dimensional shape." The wedge was positive for No. 97, and the rectangular solid for No. 156.

The results of the training which bear upon the present discussion are presented in Table 13. No. 156, trained in "stages" (i.e., proceeding from easy to more difficult tasks), and for whom the objects were available for contact after the first four days, learned the discrimination readily. No. 97, who, at first, was not trained in stages, and for whom the objects were presented behind plexiglass, failed to show improvement after 18 days and 504 trials of training. When the negative object was then replaced by a blank card, she learned readily to go to the positive object. When, however, the negative blank card was replaced by a two-inch square piece of gray paper, she showed improvement, but never reached a high, stable level of performance.

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*I am indebted to Dr. Irving T. Diamond for support in the execution of parts of this experiment.

Table 13

Performance in Object-discrimination of Two Cats under Several Different Conditions of Object Presentation (Conditions Listed in Order Tested)

Cat No. 97 (Wedge+ vs. Rectangular Solid−)

Condition	Discrimination Task	Days	Trials	Performance
Objects behind plexiglass	Wedge vs. rectangular solid	18	504	Never above 53% correct
Objects behind plexiglass	Wedge vs. blank door	4	77	90% correct on last 2 days (trials 56-77)
Objects behind plexiglass	Wedge vs. flat square	20	378	Achieved 100% twice and 90% once, but performance quite unstable; mean performance from first time 100% achieved was 83%; on last 9 days, performance varied from 67%-100%
Objects available for contact	Wedge vs. flat square	18	103	Achieved 90% and 100% on trials 84-103; performance on last 7 days was: 77%, 71%, 83%, 77%, 83%, 90%, and 100%
Objects available for contact	Wedge vs. rectangular solid	6	69	Criterion on trials 40-69; performance on last 6 days was: 70%, 90%, 77%, 90%, 100%, and 100%

Table 13 (continued)

Cat No. 156 (Rectangular Solid+ vs. Wedge−)

Condition	Discrimination Task	Days	Trials	Performance
Objects behind plexiglass	Rectangular solid vs. blank door	4	68	After day 1, mean performance was 50% correct
Objects available for contact	Rectangular solid vs. blank door	6	61	100% on each of days 3-6
Objects available for contact	Rectangular solid vs. flat square	2	20	100% correct on both days
Objects available for contact	Rectangular solid vs. wedge	4	45	93%, 90%, 100%, 100% correct

When the doors were modified so that the discriminanda were available for contact, she achieved criterion (90 percent correct on two successive days) in 11 additional days and 103 trials. She then achieved criterion on the original two-object discrimination, which she had been unable to learn previously, in less than 6 days and 69 trials.

While these results are by no means conclusive, especially in view of the small number of cats studied, and the fact that other variations than availability of the objects for contact were present, they are at least suggestive of the role played by contact in visually guided behavior, at least when certain object properties have to be reacted to in order to perform successfully. Furthermore, the nearly perfect transfer shown by No. 156 from the first to the second and third stages of training suggests that the "absolute," "three-dimensional" features of the positive object were learned from the beginning. The failure of No. 97 to obtain perfect transfer may have in some way resulted from the long previous training procedure in which she was, for the most part, unsuccessful. Such a procedure would appear to be capable of providing the basis for the formation of a number of unnecessary, and perhaps maladaptive, habits.*

These results also suggest that movement-produced changes in stimulation or accommodatory changes alone do not provide a sufficient basis for rendering three-dimensional shape effective. This statement is made quite tentatively, however, since the overall situation, including the characteristics of the objects, was not such that very great changes in retinal stimulation

*Subsequent equivalence tests indicated that No. 97 had actually learned a "sign-differentiated position habit," in that she always chose the left-hand alley when the <u>positive</u> object was on the left, and the right-hand alley when the <u>negative</u> object was on the left. Her choices were unaffected by the nature of the objects on the right.

could occur as a result of movement. It may, however, be important to point out that both cats responded appropriately to photographs of the objects, as long as the photographs were taken from an angle of approximately 30 degrees above a line normal to the frontal parallel position. (Such photographs evoke in the human observer a very compelling impression of three-dimensionality.) It may thus be concluded that movement-produced changes in visual stimulation, and perhaps accommodatory changes, are certainly not <u>necessary</u> conditions for the occurrence of appropriate choice behavior.

In considering perceptual behavioral factors related to the effectiveness of the external, or border features of the objects, emphasis is placed upon the fact that, at least for the hemisphere cats, a majority of the correct choices in the outline tests were made in the far situation (29 far to 10 near in the positive-unchanged context, and 19 far to 10 near in the negative-unchanged context. The pyramid cats made an approximately equal number of far and near choices--18 and 17, respectively--in the negative-unchanged context.) The behavior of the cats (all cats except 54--Experiment I) during the time that they were held in the detention box before being released into the choice box was not at all indicative of "visual search." Very little scanning of the objects was seen, although there was sufficient time for it to occur before release. Furthermore, very little scanning could have been accomplished between the time that the opaque door to the detention box was dropped and the animals entered, since entry into the detention box was customarily quite rapid. Once in the detention box the cats' behavior usually consisted of pawing or nosing at the plexiglass door, with little, if any, obvious attention being paid to the objects. None the less, when released from the detention chamber, they would go directly to the object chosen (on those trials scored F). It does not seem reasonable, in view of the cats' post-

release behavior, that they were not usually cognizant of the location of the correct object while in the detention box. In other words, the correct choice, when made in the detention box, apparently did not require any prolonged visual searching. It is suggested here that certain classes of information characteristic of the borders of objects may readily come to serve as an effective basis for orientation, without requiring active searching on the part of the animal. Since "three-dimensional shape" was effective for the pyramid cats in the far situation, internal features of the objects must also be capable of eliciting orientation, but only after tactual exploration of the objects in previous trials.*

In reference to these suggestions, it will be recalled that Riesen and Aarons (1959) reported that kittens reared in visual isolation, except for a brief period of unencumbered experience in patterned light per day, were perfectly capable of learning a visual movement discrimination. On the other hand, kittens subjected to the same treatment, but without being allowed to move around in the environment, were deficient visually. The encumbered kittens could presumably move their eyes and head, but not their bodies. (This is assumed, since the holder in which the kittens were kept was not described.) This datum suggests that visual search mechanisms may not be very important in the cat, at least in the absence of other kinds of perceptual behavior.

In summary, considering both border characteristics and internal fea-

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*As indicated above, there was one exception to the general statement that the cats did not appear to engage in search behavior in the detention box. Cat P4, of Experiment I, was studied further by Drs. [illegible] Lener, M. Daffron, and Mr. H. Mills. It was found that this animal's search behavior immediately prior to release was related to the direction in which it went after release.

tures of objects, it is suggested that under certain conditions the former become effective without the necessity for prolonged active search. They are considered to provide the basis for an orienting reaction, which, if acted upon, would lead the animal into a situation where more detailed information is available, either in the form of visual changes produced by movement toward the object, or tactual information resulting from contact with it. For several reasons, already mentioned, the tactual hypothesis is preferred at the present, for the findings in this situation. The "additional information" can, however, presumably come to serve as an additional basis for orientation.

Some Comparative Psychological and Neurological Considerations

The comments made in the previous section are obviously highly conjectural. While the data to which they relate would appear to require some explanation, a considerable amount of further experimentation would be necessary in order to make the above statements in an unqualified manner. If, however, subsequent experiments should support these suggestions, particularly those concerning the relationship between effective visual properties and tactual perceptual behavior, then certain intriguing possibilities for the comparative study of factors influencing visual organization would emerge. Of particular interest is the possibility that what an animal learns about an object, and is able to demonstrate with visually guided behavior, may to some degree be dependent upon the information it obtains at the same time using other sensory systems. It would be interesting to study, for example, more "optoid" animals, such as primates, in equivalent situations. It is con-

ceivable that one meaningful distinction between more and less optoid animals is related to the relative independence of the effectiveness of certain potentially effective visual properties of objects from the necessity for concomitant tactual exploratory, or perceptual behavior. Associated with this developing independence, one might expect to find an increased prominence of eye movements qua exploratory behavior (as distinguished from eye movements whose function is related primarily to orientation in space, detection of certain classes of stimuli to be approached and explored further, etc.).

As indicated previously, the study of effective object properties may also have a bearing upon the study of neural mechanisms operating in vision, particularly "selective" mechanisms. Of interest in this regard is a recent discussion of relatively modern developments in the study of the evolution of thalamocortical relationships. (Diamond and Chow, 1962) In this review, the authors are tempted to--

> imagine that the common ancestor of reptiles and mammals possessed a thalamic region which was exclusively sensory, and the projection area of this sensory thalamus was restricted to one portion of the pallium. In reptiles this area became the general cortex. In mammals a further subdivision took place and modality-specific systems emerged within the general sensory field. These modality-specific systems may be the basis for the most refined or epicritic cognitive functions. Whatever functions are made possible by the differentiation of modality-specific thalamic nuclei, it would appear from anatomy that the separation between these nuclei and the intrinsic nuclei, LP, Pul, and Po [lateralis posterior, the pulvinar, and the posterior nucleus] becomes more and more sharply drawn in an ascending series of mammals--opossum, rabbit, cat. . . . An additional development in thalamocortical projection systems is introduced by primates. The intrinsic nuclei, especially the pulvinar, develop greatly in size and achieve the specificity of cortical projections found chiefly in the extrinsic nuclei of subprimates. (1962, p. 195)

From the point of view of the present analysis, one of the most interesting facets of the discussion summarized above is the idea of a gradually emerging independence of input for visual, auditory, and somatic sensory modalities. While Diamond and Chow's primary emphasis is upon increased

intra-modality specificity, possibly manifest at the psychological level in the distinction between protopathic and epicritic sensibility, it is suggested here that a psychological implication of the structural differentiation <u>between</u> modalities may be drawn in terms of the relative independence of input to one modality from the influence of the results of, or the necessity for, simultaneous exploratory or perceptual behavior involving another modality. It would appear that research into the role of multi-modal afferent systems in the visual perceptual process would be quite valuable. It is proposed that a reasonable way to begin such work would be in studying animals before and after ablation of whatever parts of these systems are accessible, in situations such as the one reported here. The emphasis would not be primarily upon differences in capacity before and after a lesion, but upon possible changes in relationships between the effective properties of objects (i.e., the results of the operation of selective mechanisms) and the availability of correlative information from other modality systems, as affected by changes in observable perceptual behavior. The kind of experimental situation utilized in these experiments would be suitable for such an analysis.

Some Methodological Comments

In addition to the possibly important theoretical implications of the present findings, discussed above, further consideration of the two experiments leads to certain other implications with regard to methodological issues of importance for the design and execution of perceptual discrimination experiments. First of all, had Experiment I not been conducted with the aim of observing and recording as carefully as possible the discriminatory behavior of the cats, the possible fruitfulness of making a distinction between far and

near choices would never have presented itself. As it turned out, this distinction was critical in the analysis of the retinal image into its internal and external features. It was only the strong emphasis given to the desirability of a study of perceptual behavior by Wener and Gaffron (1962) that prompted the inclusion of this kind of behavioral data. Needless to say, had the experimental situation not been designed to allow flexibility in the animals' discriminatory behavior, including the specific response used as an index of choice, the information crucial to the present analysis would probably not have been obtained.

Moreover, there was no basis in the literature, other than convention and the studies of Maier (1939) and Chang (cited by Nissen and Jenkins, 1943), for considering the hemisphere cats and the pyramid cats separately. However, the results of both experiments would have been relatively meaningless had not the experimental situation been designed to permit an analysis along these lines, <u>in conjunction with</u> an analysis of the animals' behavior while discriminating. The present considerations strongly suggest that, at least in exploratory experiments such as the present ones, as many potentially relevant variables as it is possible to handle should be included in the experimental design. More specifically, the question as to whether or not, for example, "three-dimensional shape," or "outline" is a relatively more effective object property for the cat cannot be answered without taking into account other factors, such as the reward and/or punishment contingencies associated with response on the basis of these qualities, and the total sensory results of behavior of the animal in relation to the object discriminated. In a word, it would appear that a <u>detailed</u> analysis of the perceptual process at all levels currently available for analysis, including, specifically, the concomitant perceptual behavior of the animal, as is ex-

phasized by Zener and Gaffron (1962) must be undertaken if perceptual processes, particularly in animals, are to be understood in any degree of depth.

SUMMARY

Two main experiments were conducted with the aim of specifying, for the cat in an object-discrimination situation in which discrimination could be based upon several object properties, the properties that were effective in mediating the discrimination. The behavior of the animals in the discrimination situation was also observed, with the aim (1) of relating different characteristics of discriminatory behavior to the object properties determined to be effective, and (2) of enabling the determination of the nature of the retinal image of the objects when a discriminatory choice was made.

Experiment I. Five cats were trained to discriminate a horizontally-moving rough gray truncated pyramid from a vertically-moving smooth gray hemisphere. For two of the cats, the hemisphere was the correct object, and was presented along with four pyramids, the negative objects. For the other three cats the converse was the case. It was assumed that the discrimination would be based upon some combination of the properties in which the objects differed—movement direction, surface texture, outline shape, and three-dimensional shape. To assess the effectiveness of these properties test trials were run in which test objects were substituted for the positive training object, and were presented along with the four unchanged negative training objects. On any test trial the test object was like the positive training ob-

ject in one, two, or three of the above properties, and like the negative training objects in the remainder of its properties. When thus tested, none of the animals would choose the test object on the basis of movement direction alone. The cats for whom the pyramid was positive would choose on the basis of at least two of the other three properties tested separately. On the other hand, one of the hemisphere-positive cats would choose only on the basis of outline alone, and the other would choose only on the basis of the combined properties texture, outline, and three-dimensional shape. The effective property was related to the position of the cat when the choice was manifested, in that texture choices were manifested predominantly near the objects, while outline and three-dimensional shape choices were manifested predominantly at a distance.

Experiment II. In the second major experiment, ten cats (five pyramid-positive and five hemisphere-positive) were trained to the same discrimination as before, except that both positive and negative objects were moving horizontally. They were tested in the same manner as before (i.e., with test objects presented in a context of the negative training objects--the negative-unchanged context). In addition, they were tested in a situation in which the unchanged positive object was to be discriminated from four test objects which differed from it in only one or two of the three properties: texture, outline, and three-dimensional shape (the positive-unchanged context). Moreover, a brightness-control condition was introduced, in which the brightness relationship between positive and negative training and test objects was reversed.

The results are consonant with those of Experiment I, in that, for the pyramid cats, all three properties were effective singly in the negative-unchanged context, while, for the hemisphere cats, outline was the only ef-

fective single property. On the other hand, there was a marked differential effect of the context in which the tests were run for the pyramid cats, but not for the hemisphere cats. The single properties were generally effective for the pyramid cats only in the negative-unchanged context. For the hemisphere cats, outline was effective in both contexts. These results were interpreted to mean that the cats were reacting primarily to the properties of the positive object, without regard for the properties of the negative object.

The choices of the animals were categorized according to whether they were manifested at a distance or near the objects. On the basis of this categorization, the characteristics of the retinal images of the objects at the time of choice were approximately determined. When the results of the brightness-control condition were taken into account, the analysis suggested that the features of the borders of the images were effective for both hemisphere-positive and pyramid-positive cats, whereas the internal features of the images were effective only for the pyramid-positive cats.

Certain of the findings were discussed in relation to somewhat similar findings reported for the rat and the monkey by other investigators.

The results were interpreted in terms of the possible influence of the tactual features of the stimulus objects upon their effective visual properties. In support of the suggestions made, additional data were presented--partly from observation of qualitative characteristics of the animals' discriminatory behavior in the present experiments, and partly from an independent experiment.

The interpretations were considered from the point of view of their bearing upon the comparative study of visual perceptual processes, and upon the comparative study of the function of thalamocortical sensory systems in vision.

APPENDIX C

APPENDIX L. PERCENT CORRECT CHOICES (C+) AND PERCENT CORRECT CHOICES SCORED F OR I (F+) MADE BY EACH BRIGHTNESS-POSITIVE AND PYRAMID-POSITIVE CAT ON THE TRAINING TRIALS RUN ON EACH TEST DAY IN EXPERIMENT II

APPENDIX A

Day	Hemisphere-positive Cats									
	H14		H31		H32		H34		H36	
	C+	F'	C+	F'	C+	F'	C+	F'	C+	F'
1	100	60	100	50	100	65	100	40	95	60
2	95	60	95	35	95	70	95	40	95	60
3	100	60	95	45	95	75	100	25	95	40
4	95	85	100	20	100	65	100	45	100	65
5	100	85	100	25	100	100	95	35	100	75
6	95*	75	95	30	100	85	100*	50	95*	60
7	95*	65	90*	35	95*	65	90	40	95	65
8	100	75	100*	50	100*	95	95*	30	95*	60
9	95*	90	100	50	100	95	95	35	95	75
10	100*	100	95*	20	95*	85	100*	45	95*	55
11	90	85	100*	40	100*	95	95	20	90	65
12	90	90	100	60	95	95	100*	50	100*	75
13	90*	90	100*	30	95*	95	100	40	100	95
14	100	95	100	35	95	95	95*	35	100*	90
15	95	85	100	50	95	90	95	50	100	80

Day	Pyramid-positive Cats									
	P19		P30		P33		P35		P37	
	C+	F'	C+	F'	C+	F'	C+	F'	C+	F'
1	100	75	100	60	100	75	100	70	90	40
2	100	45	95	65	100	65	95	65	100	80
3	100	60	100	70	100	65	100	75	100	75
4	100	80	100	60	95	70	95	60	100	75
5	100	55	100	85	100	65	95	45	100	75
6	100	65	95	75	100	70	90*	65	100*	60
7	100	75	100	75	100	55	95	55	100	60
8	100*	65	95	55	100*	55	90*	45	100*	75
9	95*	45	100*	75	100*	60	95	70	100	60
10	95	65	95*	60	90	50	100*	75	95*	85
11	100*	65	100	70	100*	75	95	50	90	60
12	100*	65	100*	65	100*	55	95*	55	100*	60
13	100	55	95*	60	100	50	95	60	100	70
14	100*	50	95	65	100*	55	95*	65	100*	75
15	95	65	100*	70	95	55	95	55	90	60

*Brightness-reversed test day.

APPENDIX R. NUMBER OF CORRECT CHOICES BETWEEN F, [illegible], AND R FOR EACH HEMISPHERE-POSITIVE AND PYRAMID-POSITIVE RAT, EACH CONTEXT, AND EACH PROPERTY TESTED IN THE BRIGHTNESS-NORMAL CONDITION IN EXPERIMENT II

APPENDIX B

Smooth Hemisphere-positive Cats

Property Tested	H14						H31						H32						H34						H36					
	Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context		
	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N
T	3	0	1	1	0	0	1	1	5	2	0	2	1	0	1	1	0	0	2	0	1	1	0	6	0	0	0	0	0	4
O	6	0	3	4	0	3	4	0	3	0	0	3	8	0	0	5	0	3	6	0	2	5	0	3	6	0	2	4	1	1
3-D	1	0	1	1	0	4	3	0	2	0	0	5	3	0	0	0	0	3	2	0	5	0	0	4	2	0	0	3	0	5
TO	5	1	2	4	1	1	3	0	6	1	0	6	8	0	2	3	0	4	5	0	4	4	0	4	8	0	1	5	0	4
T3-D	1	2	1	4	0	3	1	0	5	1	0	6	4	1	2	1	0	7	2	0	6	2	0	4	3	0	3	1	0	8
O3-D	8	0	0	7	1	1	3	1	5	3	0	5	8	1	0	7	0	3	4	0	6	2	0	7	6	0	3	4	0	6

Rough Pyramid-positive Cats

Property Tested	P19						P30						P33						P35						P37					
	Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context		
	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N	F	N	N
T	1	0	3	0	0	6	0	0	1	2	0	7	1	1	0	0	0	6	1	0	0	2	0	5	3	0	1	2	1	3
O	2	2	2	2	2	5	5	0	0	5	0	2	3	1	0	5	0	4	4	0	0	3	0	1	1	0	0	4	0	4
3-D	3	0	1	1	0	6	3	0	1	5	0	3	0	0	1	3	1	5	2	0	5	6	0	3	2	0	0	5	2	3
TO	3	1	5	3	1	6	3	0	1	5	0	4	2	0	3	5	1	4	6	0	1	6	0	4	3	0	3	9	0	1
T3-D	3	2	5	3	0	7	5	0	3	5	0	3	1	1	3	3	0	7	5	0	4	4	0	6	3	1	1	5	0	4
O3-D	5	1	2	3	1	6	6	0	1	7	0	2	3	1	4	4	2	3	5	0	2	6	0	3	5	1	1	3	1	6

APPENDIX C. NUMBER OF INCORRECT CHOICES CODED P, N, AND B FOR EACH [illegible]-POSITIVE AND PYRAMID-POSITIVE CAT, EACH CONTEXT, AND EACH PROPERTY TESTED IN THE BRIGHTNESS-SMALL CONDITION IN EXPERIMENT II

APPENDIX C

Property Tested	Smooth Hemisphere-positive Cats																													
	H14						H31						H32						H34						H36					
	Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context		
	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N
T	6	0	0	1	2	6	2	0	1	0	0	6	7	0	1	3	0	6	3	0	4	0	0	3	9	0	1	1	0	5
O	0	0	1	0	0	3	3	0	0	0	0	7	2	1	0	1	0	1	2	0	0	0	0	2	1	0	1	0	0	4
3-D	6	0	0	0	2	3	3	0	2	1	0	4	7	0	0	3	0	4	1	0	2	1	0	5	7	0	1	1	0	1
TO	1	1	0	2	0	2	0	0	1	0	0	1	0	0	0	1	1	1	1	0	0	0	0	2	0	0	1	0	0	1
T3-D	4	0	2	0	1	2	1	0	3	0	0	3	3	0	0	2	0	0	1	0	1	1	0	3	4	0	0	1	0	0
O3-D	2	0	0	0	0	1	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0

Property Tested	Rough Pyramid-positive Cats																													
	P19						P30						P33						P35						P37					
	Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context			Positive-unchanged Context			Negative-unchanged Context		
	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N	F	M	N
T	3	0	3	1	0	3	6	0	3	1	0	0	3	1	4	1	1	2	9	0	0	2	0	1	6	0	0	1	0	3
O	1	1	2	0	0	1	3	0	2	1	0	1	2	0	4	0	0	1	6	0	0	2	0	4	9	0	0	1	0	1
3-D	3	0	3	1	0	2	6	0	0	2	0	0	5	0	4	0	0	1	3	0	0	0	0	1	7	0	1	0	0	0
TO	1	0	1	0	0	0	3	0	3	0	0	1	3	2	0	0	0	0	3	0	0	0	0	0	3	1	0	0	0	0
T3-D	0	0	0	0	0	0	2	0	0	0	0	0	3	0	2	0	0	1	1	0	0	0	0	0	5	0	0	0	0	1
O3-D	2	0	0	0	0	0	2	0	1	0	0	1	1	0	1	0	0	1	1	0	2	0	0	1	0	0	3	0	0	0

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BIOGRAPHICAL DATA

Name: Walter Francis Daves

Born: October 3, 1935
Atlanta, Georgia

Education: Emory University, B.A., 1957; M.A., 1959
Duke University, 1959 to present

Positions: Departmental Assistant, Emory University, 1958

Psychology Trainee, Veterans Administration Hospital, Durham, North Carolina, 1959, 1960, 1962

Research Assistant, Department of Psychology, Duke University, 1961

Part-time Instructor, Department of Psychology, Duke University, 1962

Memberships: Southern Society for Philosophy and Psychology

Honors: Emory University Fellow, 1958
USPHS Fellow, Duke University, 1959, 1960-61, 1961-62
James B. Duke Fellow, Duke University, 1959-60
Sigma Xi

Publications: Bevan, W., Daves, W. F., and Levy, G. W. The relation of castration, androgen therapy, and pre-test fighting experience to competitive aggression in male C57 Bl/10 mice. Animal Behaviour, 1960, 8, 6-12.

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